APR 9 1987

I49.89/2:86(3)

BIOLOGICAL REPORT 86(3)
JUNE, 1986

ORIGINAL

ENVIRONMENTAL BASELINE STUDIES DURING 1984 OF LAKE NICOLET AND MUNUSCONG BAY, ST. MARYS RIVER, MICHIGAN, IN RELATION TO PROPOSED EXTENSION OF THE NAVIGATION SEASON

COMPLETED
410

Fish and Wildlife Service
U.S. Department of the Interior

Corps of Engineers
U.S. Department of the Army

ENVIRONMENTAL BASELINE STUDIES DURING 1984 OF LAKE NICOLET AND MUNUSCONG BAY, ST. MARYS RIVER, MICHIGAN, IN RELATION TO PROPOSED EXTENSION OF THE NAVIGATION SEASON

Charles R. Liston and Clarence D. McNabb
Principal Investigators
Department of Fisheries and Wildlife
Michigan State University
East Lansing, Michigan. 48824-1222

PART I. LIMNOLOGICAL AND FISHERIES STUDIES OF MUNUSCONG BAY, ST. MARYS RIVER, DURING 1984

Charles Liston, Guy Fleischer, Dan Brazo,
Walt Duffy, Joe Bohr, and Sara Chubb

PART II. EFFECTS OF COMMERCIAL SHIP PASSAGE ON EMERGENT WETLANDS IN LAKE NICOLET, ST. MARYS RIVER, 1984

Clarence McNabb, Ted Batterson, John Craig,
Paul Roettger and Mehdi Siami

U.S. Fish and Wildlife Service Contract No. 14-16-0009-84-029
Project Officers- Keith Kraai and William Aultfather
U.S. Fish and Wildlife Service
Twin Cities, Minnesota. 55111.

Major funding for this study was provided by
U.S. Army Corps of Engineers
Detroit District Office

This study was co-sponsored by
Department of Fisheries and Wildlife
Michigan State University
and
the Michigan Agricultural Experiment Station

performed for
Office of Biological Services
Fish and Wildlife Services
U.S. Department of Interior

ENVIRONMENTAL BASELINE STUDIES DURING 1984 OF LAKE NICOLET AND MUNUSCONG BAY, ST. MARYS RIVER, MICHIGAN, IN RELATION TO PROPOSED EXTENSION OF THE NAVIGATION SEASON

Charles R. Liston and Clarence D. McNabb
Principal Investigators
Department of Fisheries and Wildlife
Michigan State University
East Lansing, Michigan. 48824-1222.

PART I. LIMNOLOGICAL AND FISHERIES STUDIES OF MUNUSCONG BAY, ST. MARYS RIVER, DURING 1984

by

Charles Liston, Guy Fleischer, Dan Brazo,
Walt Duffy, Joe Bohr, and Sara Chubb

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report/product are those of the authors and do not necessarily reflect the view of the Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, and the Corps of Engineers, U.S. Department of the Army, nor does mention of trade names of commercial products constitute endorsement or recommendation for use by the federal government.

TABLE OF CONTENTS

Page

PREFACE vi

EXECUTIVE SUMMARY vii

LIST OF FIGURES ix

LIST OF TABLES xi

LIST OF ABBREVIATIONS, SYMBOLS, AND CONVERSIONS xiv

LIST OF COMMON AND SCIENTIFIC NAMES OF FISHES xv

ACKNOWLEDGEMENTS xvi

INTRODUCTION 1

STUDY SITE 3

METHODS AND MATERIALS 6

PHYSICAL AND CHEMICAL ASPECTS 6

Water Chemistry, Temperature, and Turbidity 6
Winter Sediment Rates 6

BENTHIC MACROINVERTEBRATES 11

Field Methods 11
Laboratory Methods 11
Data Presentation 11

FISH LARVAE 11

Field Collecting 11
Channel and Deep Water Sampling 11
Shallow, Open Water Sampling 14
Shallow Littoral Sampling 14
Laboratory 14
Data Presentation 14

Page

JUVENILE AND ADULT FISH 16

Trawls 16
Small-Mesh Trap Nets 16
Large-Mesh Trap Nets 19

RESULTS AND DISCUSSION 20

PHYSICAL AND CHEMICAL ASPECTS 20

Water Temperature 20
Dissolved Oxygen 20
Turbidity 20
Winter Sedimentation 25

BENTHIC MACROINVERTEBRATES 33

Taxonomic Composition 33
Chironomidae 33
Oligochaeta 33
Ephemeroptera 33
Trichoptera 33
Gastropoda and Pelecypoda 33
Amphipoda 39
Isopoda 39
Ostracoda 39
Littoral vs. Offshore Areas 39
Regional Distribution and Abundance 40
Lake Munuscong vs. St. Marys River 41

FISH LARVAE 42

Major Taxa 44
Cyprinidae 44
Rainbow smelt 48
Yellow perch 48
Black crappie 52
Lepomis spp. 52
Lake herring and lake whitefish 54
Walleye 57
Pink salmon 60
Burbot 60
Gizzard shad 60
Other percids 60

Page

JUVENILE AND ADULT FISH 61

Bottom Trawls 61
Trout-perch 66
Yellow perch 66
Johnny darter 69
Spottail shiner 69
Mimic shiner 72
Other species 74
Small-Mesh Trap Nets 74
Large-Mesh Trap Nets 75
Mark/recapture data 80

SUMMARY 92

PHYSICAL AND CHEMICAL ASPECTS 92

BENTHIC MACROINVERTEBRATES 93

FISH LARVAE 93

JUVENILE AND ADULT FISH 94

LITERATURE CITED 96

APPENDIX A. Physical and chemical data taken in Munuscong Bay during various fish sampling programs in 1984. A1-A7

APPENDIX B. Collection records for each benthic macroinvertebrate sample including date, gear type (PONAR or Ekman dredge), station/site, density (no./m^2) and descriptive statistics for each taxa. B1-B14

APPENDIX C. Collection records for each larval fish sample including station, time, water volume filtered (m^3), and number of larvae of each taxa. C1-C42

APPENDIX D. Catch records of fish collected with trawls in Munuscong Bay, 1984. D1-D27

APPENDIX E. Catch records of fish taken with large-mesh trap nets including numbers tagged from Munuscong Bay, 1984. E1-E12

PREFACE

Though potential direct effects of extended season commercial shipping are of special concern in narrow channel areas of the St. Marys River, back-water connected bays such as Munuscong Bay support a high diversity of fisheries resources and an environmental baseline study would be incomplete without some quantification of limnological and fisheries aspects associated with these habitats. Previous studies have documented environmental conditions from channel to shoreline at seven major sites along approximately 64 km (40 mi) of the St. Marys River. The present study, although more limited in scope, employed comparable techniques in studying physical and chemical aspects, aquatic invertebrates, and fishes (larvae, juveniles and adults) within Munuscong Bay, one of the most important sport fishing areas within the St. Marys River system. As with previous studies, the methodologies may be readily replicated, if desired, for direct future comparisons should extended season shipping be implemented.

This report was submitted by the Department of Fisheries and Wildlife, Michigan State University in fulfillment of contract number 14-16-0009-84-029 under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Technical review was provided by personnel of the Detroit District, U.S. Army Corps of Engineers. Major funding was provided by the U.S. Army Corps of Engineers, with additional support from the U.S. Fish and Wildlife Service, Michigan State University and the Michigan Agricultural Experiment Station.

The address of the information transfer specialist for this study is as follows:

Information Transfer Specialist
Office of Biological Services
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, MN. 55111.

Charles R. Liston
Associate Professor
Dept. Fisheries and Wildlife
Michigan State University
East Lansing, MI. 48824-1222.

Clarence D. McNabb
Professor
Dept. Fisheries and Wildlife
Michigan State University
E. Lansing, MI. 48824-1222.

EXECUTIVE SUMMARY

Baseline environmental data were gathered during January to September, 1984, in Munuscong Bay, St. Marys River, by the Department of Fisheries and Wildlife, Michigan State University, through a contract with the U. S. Fish and Wildlife Service, and with funding by the U.S. Army Corps of Engineers. The data were taken in relation to proposed extension of the navigation season, and were supplementary to previous extensive data taken near the navigation channels. Munuscong Bay was selected for study given its location directly below narrow shipping lanes, its general accessibility to sampling, and high sports fishing value. Data were taken on winter sedimentation, turbidity, dissolved oxygen, water temperatures, benthic macroinvertebrates, and fishes (larval, juveniles and adult life stages).

Winter sedimentation rates determined from under-ice traps ranged from approximately 120 to 8,000 mg/day/m^2 with generally higher rates observed in March compared to February. Sedimentation was lower near the navigation channel compared to sites close to local tributaries. Particle size fractions including <10 u, 10-60 u, and > 60 u sizes were analyzed from sediments collected. Much of the sediment load near the channel was fine clay which remains in suspension for considerable periods. Water turbidity ranged from 1.7-86 NTU. Turbidity appeared to be related to wind-induced disturbances and run-off from local tributaries rather than to navigational activities. Water temperatures warmed from 3-7 °C in April to 20-24 °C in August. Nearshore waters were warmer than the channel by several degrees throughout the sample season. Dissolved oxygen ranged between 7 and 13 mg/l.

A total of 24 Ekman and 30 PONAR grab samples collected benthic invertebrates at 4 inshore and 10 open-water sites. Forty-six taxa of benthic invertebrates were identified including important groups such as Chironomidae, Oligochaeta, Ephemeroptera (3 genera), Trichoptera (ten genera), Gastropoda (9 genera), Pelecypoda (3 genera), Amphipoda (3 genera), Isopoda (2 genera), and Ostracoda. Total invertebrate abundances ranged from 3,168-27,456/m^2 and 2,756-24,397/m^2 in Ekman and PONAR samples, respectively.

The larval fish community was sampled during April through August in channel areas, shallow open-water areas, and shallow littoral (macrophyte) areas. Some 33 taxa of 12 families were identified from 6,731 larval fish collected. Rainbow smelt, emerald shiner and yellow perch dominated, although 9 other taxa were considered common including Cyprinidae, spottail shiner, black crappie, logperch, common carp, Lepomis spp., gizzard shad, johnny darter, and lake herring. Seasonal trends were clear. Early larvae included coregonids and burbot, late spring larvae were comprised mainly of rainbow smelt and yellow perch, and summer larvae were predominantly Cyprinidae, Percidae (logperch and johnny darter), and Centrarchidae (Lepomis spp. and

black crappie). The littoral zone with abundant macrophytes harbored high densities of carp, emerald shiner, and Centrarchidae while the inflowing tributaries and downbound channel area appeared more suitable for larval species such as rainbow smelt, yellow perch, lake herring and walleye.

Bottom trawls during May through August (32 samples) demonstrated a high diversity (27 species) of small juvenile forage and sport fish. Trout-perch, yellow perch, mimic shiner, and spottail shiner dominated the demersal community collectively comprising nearly 85% of the catch.

Small-mesh trap nets deployed in upper littoral vegetated areas further revealed the presence of a high diversity of small juvenile and forage fishes. Twenty-five species were identified, although young yellow perch were dominant (31.8%) followed by juvenile black crappie (18.6%), various cyprinid species, rock bass, brown bullhead, pumpkinseed sunfish, smallmouth bass, and walleye. Of the 12 most common species, over 95% were young-of-the-year or yearlings.

Large trap nets set during April to September sampled large adult fish present in Munuscong Bay. Nineteen species were identified in the collection although adult walleye and white sucker clearly dominated the catch. Adult walleye were in greatest abundance in Munuscong Bay compared to other sites along the St. Marys River where large trap nets have been used. Walleye were particularly abundant during early spring near a dredge spoil site and along the southern, rocky shore, perhaps utilizing these areas as spawning sites. White sucker seemed to prefer areas closer to the navigation channel, as did yellow perch, black crappie, and burbot. Throughout the year, off-channel regions seemed more favorable to walleye, channel catfish, pumpkinseed sunfish and redhorses.

The 1984 data have primary value in assessing the environmental resources of Munuscong Bay and facilitating an evaluation of potential effects of extended season navigation. The abundant benthic invertebrates and diversity of fish species (38 species from this study) which support an important sport fishery indicates that these off-channel, lentic areas are valuable resources of the St. Marys River system. Extended season navigation could affect Munuscong Bay through physical disruption of ice flows. Under-ice disturbances from waves and currents created by passing ships may also be of significance near the navigation channel. Potential resuspension of under-ice sediments upstream toward Lake Nicolet could result in higher levels of turbidity during winter. We recommend that winter monitoring of physical parameters of Munuscong Bay such as turbidity, sedimentation rates, and under-ice currents be undertaken should extended season navigation be implemented. If changes in physical parameters occur, additional data on the biota may be necessary to help understand potential overall impacts. Further, more knowledge of the nature and value of the winter sports fishery in Munuscong Bay should be obtained.

LIST OF FIGURES

Figure		Page
1	Map of the St. Marys River showing major islands, channels, lakes, and position of Lake Munuscong.	4
2	Map of Munuscong Bay, St. Marys River, showing depth contours, (ft.) and other extent of emergent wetlands.	5
3	Map of Munuscong Bay showing generalized sampling stations 1-8 and reference landmarks.	7
4	Diagram of the sediment trap device used to estimate sedimentation in Munuscong Bay.	8
5	Map of Munuscong Bay showing PONAR (P1, P2, P2A, P3, P4, P5, P7, P7A, P8, P8A) and Ekman dredge (E1, E2, E6, E8) sampling sites.	12
6	Map of Munuscong Bay showing meter tows (C2, C3, C7), push net (S1- S8), and pull net (L1, L2, L8) sampling sites in channels, nearshore, and littoral areas, respectively.	13
7	Map of Munuscong Bay showing bottom trawl sampling sites.	17
8	Map of Munuscong Bay showing small-mesh trap net (1AS, 1S, 1BS, 2S, 4S, 5S, 6S, 8S) and large-mesh trap net (2L, 3L, 5L, 8L) sampling sites.	18
9	Water temperatures at offshore (tow net), macrophyte edge (push net), and shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.	21
10	Average water temperatures at larval fish sampling stations of the near channel (2,3,7), mid bay (4), southern shore (6,8), and tributary inflow (1).	22
11	Dissolved oxygen at offshore (tow net), macrophyte edge (push net), and shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.	23

Figure		Page
12	Average dissolved oxygen at larval fish sampling stations of the near channel (2,3,7), mid bay (4), southern shore (6,8), and tributary inflow (1).	24
13	Turbidity at offshore (tow net), macrophyte edge (push net), and shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.	26
14	Average turbidity at larval fish sampling stations of the near channel (2,3,7), mid bay (4), southern shore (6,8), and tributary inflow (1).	27

LIST OF TABLES

Table		Page
1	Description of 1984 winter sedimentation sampling stations and exposure periods in Munuscong Bay, St. Marys River.	9
2	Descriptive statistics of larval fish samples in the littoral (pull net), nearshore (push net), and channel/deepwater zones (tow net) of Munuscong Bay, 1984.	15
3	Range, mean, and standard deviation for weights of sediment collected during winter in Munuscong Bay, St. Marys River, 1984.	28
4	Sediment collection rate and sedimentation rate per unit area during winter in Munuscong Bay, St. Marys River, 1984.	29
5	Maximum calculated suspended sediment concentration measured during 1984 in Munuscong Bay, St. Marys River.	31
6	Percent composition (by weight) of particle size ranges for sediment collected during winter, 1984, in Munuscong Bay, St. Marys River, 1984.	32
7	Density estimates (no./m^2) for benthic macroinvertebrates collected with PONAR grabs from Munuscong Bay, St. Marys River, during May 1984.	34
8	Abundance estimates (no./m^2) for benthic macroinvertebrates collected with Ekman grabs from Munuscong Bay, St. Marys River, during May 1984.	37
9	Total number and percentage composition of fish larvae collected from Munuscong Bay in 1984.	43
10	Mean densities (no./100 m^3) of spottail shiner larvae collected in Munuscong Bay, St. Marys River, 1984.	45
11	Mean densities (no./100 m^3) of emerald shiner larvae collected in Munuscong Bay, St. Marys River, 1984.	46
12	Mean densities (no./100 m^3) of carp larvae collected in Munuscong Bay, St. Marys River, 1984.	47

Table Page

13 Mean densities (no./100 m^3) of Cyprinidae larvae collected in Munuscong Bay, St. Marys River, 1984. 49

14 Mean densities (no./100 m^3) of rainbow smelt larvae collected in Munuscong Bay, St. Marys River, 1984. 50

15 Mean densities (no./100 m^3) of yellow perch larvae collected in Munuscong Bay, St. Marys River, 1984. 51

16 Mean densities (no./100 m^3) of black crappie larvae collected in Munuscong Bay, St. Marys River, 1984. 53

17 Mean densities (no./100 m^3) of *Lepomis* spp. larvae collected in Munuscong Bay, St. Marys River, 1984. 55

18 Mean densities (no./100 m^3) of lake herring larvae collected in Munuscong Bay, St. Marys River, 1984. 56

19 Mean densities (no./100 m^3) of lake whitefish larvae collected in Munuscong Bay, St. Marys River, 1984. 58

20 Mean densities (no./100 m^3) of walleye larvae collected in Munuscong Bay, St. Marys River, 1984. 59

21 Mean densities (no./100 m^3) of johnny darter larvae collected in Munuscong Bay, St. Marys River, 1984. 62

22 Mean densities (no./100 m^3) of logperch larvae collected in Munuscong Bay, St. Marys River, 1984. 63

23 Total number, total weight (grams), and percentage composition of fish captured by trawl in Munuscong Bay during 1984. 64

24 Catch-per-effort of fish at various trawl stations in Munuscong Bay during 1984. 65

25 Length-frequency composition (%) of trout-perch taken by trawls from Munuscong Bay, St. Marys River, 1984. 67

26 Length-frequency composition (%) of yellow perch taken by trawls from the Munuscong Bay, St. Marys River, 1984. 68

27 Length-frequency composition (%) of johnny darter taken by trawls from Munuscong Bay, St. Marys River, 1984. 70

Table		Page
28	Length-frequency composition (%) of spottail shiners taken by trawls from Munuscong Bay, St. Marys River, 1984.	71
29	Length-frequency composition (%) of mimic shiner taken by trawls from Munuscong Bay, St. Marys River, 1984.	73
30	Total Numbers and percent composition of fishes caught in small mesh trap nets set in Munuscong Bay of the St. Marys River, 1984.	76
31	Comparison of the numbers and percent composition of fishes caught in July and August in small mesh trap nets set in Munuscong Bay, St. Marys River, 1984.	77
32	Numbers of fishes collected with large trap nets in Munuscong Bay, St. Marys River, 1984.	78
33	Numbers of fishes collected with large trap nets at various stations in Munuscong Bay, St. Marys River, 1984.	79
34	Length-frequency of walleye caught in large trap nets set in Munuscong Bay, 1984.	81
35	Length-frequency of channel catfish caught in large trap nets set in Munuscong Bay, 1984.	82
36	Length-frequency of northern pike caught in large trap nets set in Munuscong Bay, 1984.	83
37	Length-frequency of white sucker caught in large trap nets set in Munuscong Bay, 1984.	84
38	Length-frequency of rock bass caught in large trap nets set in Munuscong Bay, 1984.	85
39	Length-frequency of yellow perch caught in large trap nets set in Munuscong Bay, 1984.	86
40	Length-frequency of black crappie caught in large trap nets set in Munuscong Bay, 1984.	87
41	Length-frequency of smallmouth bass caught in large trap nets set in Munuscong Bay, 1984.	88
42	Tag, release and recapture data for fish collected with large-mesh trap nets in Munuscong Bay, 1984.	89
43	Numbers of fish tagged and released after capture in large-mesh trap nets at each of four stations in Munuscong Bay during 1984 (numbers recaptured in parenthesis).	90

LIST OF ABBREVIATIONS, SYMBOLS, AND CONVERSIONS

°C	Celcius, degree
cm	Centimeter (0.3937 inches)
cm^2	Square centimeter (0.155 square inches)
CPE	Catch per effort
cm/d	Centimeters per day
d	Day
/d	Per day
ft	Foot (feet)
g	Gram (0.035 ounces)
hr^{-1}	Per hour
km	Kilometer (0.6214 mile)
l	Liter (0.264 gallon)
log	Logarithm to base 10
L	Length
mi	Mile (1.609 km)
m	Meter (3.28 feet)
mg	Milligram (0.001 g)
mg/d	Milligrams per day
$mg/d/m^2$	Milligrams per day per square meter
ml	Milliliter (0.128 fluid ounces)
m^3	Cubic meter (35.29 cubic feet)
mm	Millimeter (0.0394 inches)
m^2	Square meter (10.76 square feet)
mg/l	Milligrams per liter
m^{-1}	Per square meter
mg/cm^2	Milligrams per square centimeter
m/sec	Meters per second
mph	Miles per hour
$no./m^2$	Number per square meter
NTU	Nephelometric turbidity unit
r^2	Correlation coefficient
sec^{-1}	Per second
TL	Total length
u	Micron or micrometer (one millionth of a meter)
ug	Microgram
ug/l	Micrograms per liter
N Lat	North latitude
YOY	Young-of-the-year fish
W Long	West longitude
≤	Less than
≥	Greater than
≥	Greater than or equal to
≤	Less than or equal to
=	Equal to
o	Degrees
10^3	1000
10^5	One hundred thousand
%	Percent
'	Feet or minutes
"	inches or seconds

LIST OF COMMON AND SCIENTIFIC NAMES OF FISHES

Common names of fishes have been standardized in "A List of Common and Scientific Names of Fishes from the United States and Canada", 4th edition, 1980, American Fisheries Society Special Publication No. 6. The following is an alphabetical list of fish species collected during this study with appropriate scientific names.

Alewife	*Alosa pseudoharengus*
Black crappie	*Pomoxis nigromaculatus*
Bluntnose minnow	*Pimephales notatus*
Bowfin	*Amia calva*
Brook stickleback	*Culaea inconstans*
Brown bullhead	*Ictalurus nebulosus*
Burbot	*Lota lota*
Channel catfish	*Ictalurus punctatus*
Common carp	*Cyprinus carpio*
Common shiner	*Notropis cornutus*
Deepwater sculpin	*Myoxocephalus quadricornis*
Emerald shiner	*Notropis atherinoides*
Freshwater drum	*Aplodinotus grunniens*
Gizzard shad	*Dorosoma cepedianum*
Golden shiner	*Notemigonus crysoleucas*
Iowa darter	*Etheostoma exile*
Johnny darter	*Etheostoma nigrum*
Lake herring	*Coregonus artedii*
Lake whitefish	*Coregonus clupeaformis*
Logperch	*Percina caprodes*
Longnose sucker	*Catostomus catostomus*
Mimic shiner	*Notropis volucellus*
Mottled sculpin	*Cottus bairdi*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Pink salmon	*Oncorhynchus gorbuscha*
Pumpkinseed	*Lepomis gibbosus*
Rainbow smelt	*Osmerus mordax*
Rock bass	*Ambloplites rupestris*
Sand shiner	*Notropis stramineus*
Shorthead redhorse	*Moxostoma macrolepidotum*
Silver redhorse	*Moxostoma anisurum*
Smallmouth bass	*Micropterus dolomieui*
Spottail shiner	*Notropis hudsonius*
Trout-perch	*Percopsis omiscomaycus*
Walleye	*Stizostedion vitreum*
White sucker	*Catostomus commersoni*
Yellow perch	*Perca flavescens*

ACKNOWLEDGEMENTS

This study has required the cooperation of many persons and organizations. The authors were assisted in the gathering and analysis of field data by Mr. Mike Thomas, graduate student, and undergraduate students of the Department of Fisheries and Wildlife, Michigan State University. We thank Mr. Leo Yeck, Ludington, Michigan, for taking time to counsel us on fishing gear and net maintenance.

Mr. Gerald Haarer, Director of the Land Management Office , Michigan State University, is gratefully thanked for his help in securing off-campus work and living quarters at the MSU Dunbar Research Station, Barbeau, Michigan. Much of the analysis of field samples and secretarial support was coordinated and conducted at the MSU Fisheries Laboratory at Ludington, Michigan.

The valuable ideas and interests shown by Marge Kolar, Rich Greenwood, and T.J. Miller, U.S. Fish and Wildlife Service, East Lansing Office, are appreciated. Mr. Walter Mikula, MDNR Area Law Enforcement Officer, is acknowledged for fielding many questions from citizens.

The computer space, administrative assistance and facilities provided by the Department of Fisheries and Wildlife, Michigan State University, was important for completion of this report. Partial staff salaries for this project were provided by the Michigan Agricultural Experiment Station.

Mr. Keith Kraai, Ms. Doris Medly, Ms. Linda Boor, and Mr. William Aultfather, U.S. Fish and Wildlife Service, have been most understanding and helpful with contract administrative duties. Similarly, the many hours in contract administration given by Mr. Howard Grider, Mr. Gene Stauffer, and Ms. Pat Patton, Michigan State University Contracts and Grants Department, are gratefully recognized. We also appreciate the administrative assistance, patience and encouragement given by Mr. Les Weigum, Dr. Jim Galloway, Mr. Don Williams, Mr. Tom Freitag and Mr. Dan Thompson of the U.S. Army Corps of Engineers, Detroit District. Finally, the U.S. Army Corps of Engineers, Detroit District, is thanked for their overall interest displayed in this project and in providing major funding. Funding for report preparation and data analysis was provided by the U.S. Fish and Wildlife Service, Michigan State University, and the Michigan Agricultural Experiment Station.

INTRODUCTION

The St. Marys River connects Lakes Superior and Huron, and is the major commercial navigation shipping link between the northcentral United States and major industrial ports of the lower Great Lakes (Figure 1). Commercial shipping through this seaway has traditionally occurred from early April through mid-December. However, a shipping season extending into the winter months has long been considered and year-round shipping was shown to be feasible. A limited season extension to approximately 8 January was implemented in 1979, and a further extension to 31 January has been proposed (U.S. Army Corps of Engineers, Detroit District, personal communication).

From 1979 through 1984, the Department of Fisheries and Wildlife, Michigan State University has conducted studies of baseline environmental conditions of the St. Marys River through contract with the U.S. Fish and Wildlife Service and major funding by the U.S. Army Corps of Engineers. These studies were performed to assess potential dredging impacts within, and adjacent to, the navigation channels (Liston et al. 1980) and natural annual changes in environmental parameters and potential impacts of extended shipping on nearshore zones (Liston et al. 1981) and within Lake George, a connecting channel and lake not used for commercial shipping (Liston et al. 1983). While these previous studies focused on a limited area near Neebish Island, midway along the river system, studies in 1982 and 1983 were expanded to include stations covering approximately 64.4 km (40 mi) of river from above the Soo Locks at Sault Ste. Marie to the Round Island shipping course near Lime Island (Figure 1; Liston et al. 1985).

Through the course of these investigations, it became apparent that shallow nearshore and littoral areas were the major sites of primary productivity and often provided ample spawning and nursery habitats for a high diversity of fishes. Furthermore, previous data collections in Lake George (Liston et al. 1983) and pilot studies in Lake Munuscong indicated off-channel lentic environments may also support high productivity and diversity. However, these off-channel bays and lakes are expected to exhibit considerable amounts of wind-induced turbidity which may or may not supersede potential increases in turbidity due to the extension of the winter shipping season (Liston et al. 1983).

Therefore, in 1984, sampling effort was concentrated on Munuscong Bay to document environmental and biological conditions of one such lentic system. Objectives were to measure winter sedimentation, basic physical/chemical conditions, and to determine spatial and temporal abundance and distribution of benthic invertebrates and fishes (at all life stages). Sampling techniques were established which were comparable to those previously used in other parts of the St. Marys River.

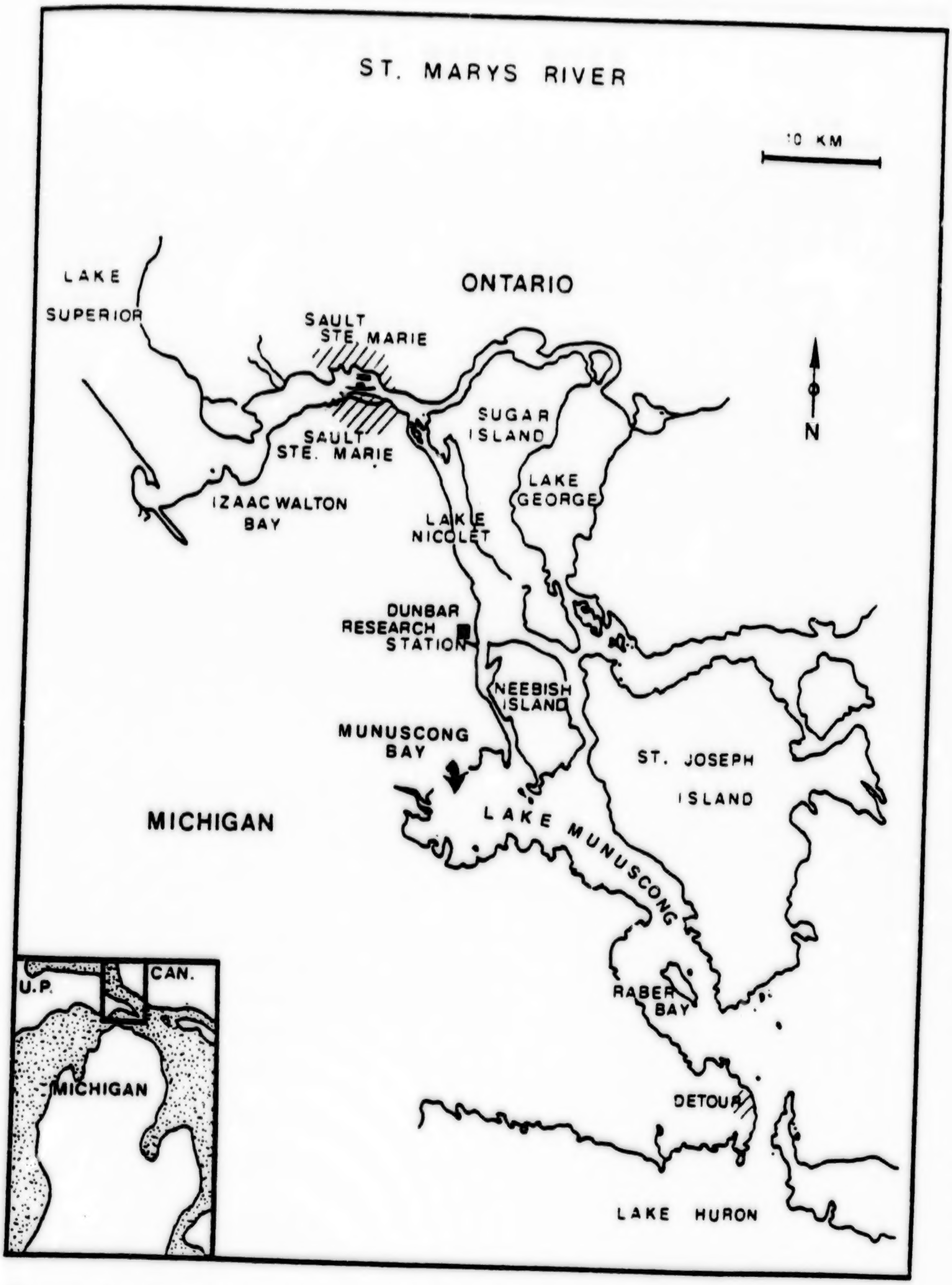

Figure 1. Map of the St. Marys River showing major islands, channels, lakes, and position of Lake Munuscong.

STUDY SITE

The St. Marys River is the only outflow of Lake Superior to the lower Great Lakes and flows about 120.7 km (75 mi) from headwaters in Whitefish Bay, Lake Superior, to Lake Huron at Detour, Michigan (Figure 1). The river descends approximately 6.7 m (22 ') with most of the drop occurring at the St. Marys Rapids and Soo Locks at Sault Ste. Marie. Below Sault Ste. Marie, the river divides into several channels and shallow lakes. Waters flow around Sugar, Neebish, and finally St. Joseph Islands. Major lakes include Lake George to the north and Lake Munuscong to the south of Neebish Island (46 N Lat.; 84 W Long.). Unlike Lake George which is isolated from the navigation channel, ship traffic passes through the north bay and southeastern extensions of Lake Munuscong (Figure 2).

The north Bay of Lake Munuscong is approximately 10 km (6.2 mi) along its east-west axis and 8 km (4.9 mi) in width. This body of water covers over 4,500 hectares (11,375 acres) and includes a diversity of habitats. The eastern end of Munuscong Bay is an open channel with the downbound navigation course crossing the middle of an elongate basin.

Munuscong Bay is characterized by convoluted shorelines of shallow vegetated coves and rocky points. The Munuscong and Little Munuscong Rivers enter the bay at the western end which is characterized by shallow, silty, vegetated bays. Emergent macrophytes are common along the shoreline and extend well into the bay. Emergents extended out to about 1 m (3.3') in depth. Submergent vegetation was dense and interspersed among emergent stands. However, submergents were sparse over much of the open-water bay, presumably due to high water turbidity and wave action.

The St. Marys River and downbound navigation channel enter the bay at the north. In this region, depths were typically 3-6 m (10-20') with a maximum depth of about 8.5 m (28 ') near the navigation channel. Substrates were typically mud and clay, although rocky outcroppings were prevalent around the Moon Islands. Rocky substrates also occurred along the southern shore of Munuscong Bay, especially around Roach and Birch Points. In these areas, depths drop off rapidly to 3-9 m (10-30') resulting in a limited near-shore zone of emergent macrophytes. A dredge spoil site is located midway between Roach Point and the navigation channel. This area is also characterized by rocky substrates and uneven bottom topography. Depths range from 3 to 15.2 m (10-50') within the spoils site.

A channel to lake profile can be derived from detailed vegetative mapping completed between Birch Point and the channel in 1982 (Liston et al. 1985; Figure 2). Chara globularis and Nitella flexilis dominated the lake bottom from 2.1 to 5.9 m in depth with widely spaced patches of Potamogeton richardsonii at depths between 1.5 to 2.0 m. Emergent macrophytes grew in

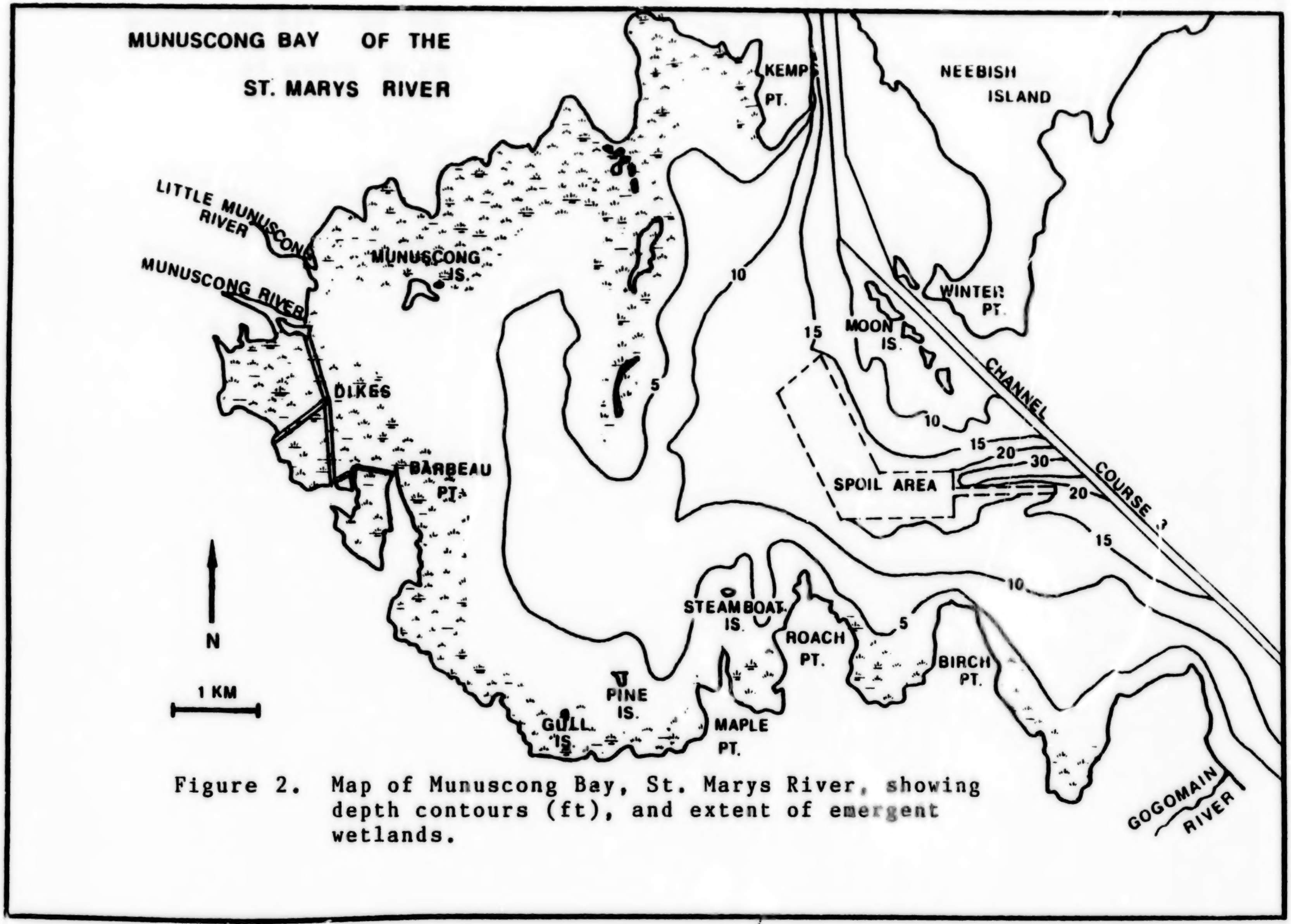

Figure 2. Map of Munuscong Bay, St. Marys River, showing depth contours (ft), and extent of emergent wetlands.

sheltered areas to depths of 2.0 m and included areas of both monotypic and mixed dominance of *Eleocharis smallii* and *Scirpus acutus*. Peak annual above-ground emergent biomass tended to occur in September at all St. Marys River sample sites (Liston et al. 1985).

METHODS AND MATERIALS

All physical, chemical, and biological samples were collected between January and September of 1984. Eight general sampling stations (1-8) were established (Figure 3). All gear types were not deployed at each station due to habitat and substrate variability and time constraints. However, replicate samples were often taken in appropriate locations, and these were designated as substations with a letter (i.e. 2A). In general, sampling was conducted across four major areas including: station 1 of the shallow west shore; station 2 of the north shore near the navigation channel; stations 3-6 representing mid-bay or open water conditions; and, stations 7-8 within the southern bay (Figure 3).

PHYSICAL AND CHEMICAL ASPECTS

Water Chemistry, Temperature, and Turbidity

Physical and chemical parameters were measured in conjunction with biological sampling throughout Munuscong Bay in 1984 (Appendix A-E). Water temperature was measured just below the surface (0.5 m) with a hand-held thermometer or YSI thermistor (Yellow Springs Instrument Co., Yellow Springs, Ohio). Dissolved oxygen samples were collected at mid-depth (1-2 m) with a 3.5 l capacity Van Dorn bottle (Wildlife Supply Co., Saginaw, Michigan) and analyzed by the azide modification of the Winkler titration. Turbidity samples were collected just below the water surface and analyzed with a Hach (model 2100A) turbidimeter (Hach Chemical Co., Ames, Iowa).

Winter Sedimentation Rates

Winter sedimentation was measured at 10 study sites (all but station 6) in Munuscong Bay (Figure 3). Sediment traps consisted of four 30.5 PVC collection tubes (2.5 cm inside diameter) strapped securely to a 15.2 cm metal frame (Figure 4). On 11 and 17 January, holes were cut through the ice at various stations and two sediment traps were lowered to the bottom. The position of each site was determined by sextant readings of three prominent landmarks and marked with a stake in the ice. At each station, one sediment trap was removed on 13-14 February. The second trap was left for an extended exposure period through 14 March (Table 1). A second exposure was not possible at station 2A. The sediment traps were carefully brought to the surface so as not to disturb the contents. The supernatant water was gently poured off and the tops sealed with rubber stoppers for transport to the laboratory.

All samples were frozen until later analysis in mid-April 1984. Samples were removed, thawed and rinsed from the collection tubes. Sediments were washed and filtered through a pre-dryed (24 hours at 100 °C), pre-weighed 0.4 u membrane filter. Next the filter paper and its contents were dryed at 100° C for at least 24 hours to a constant weight.

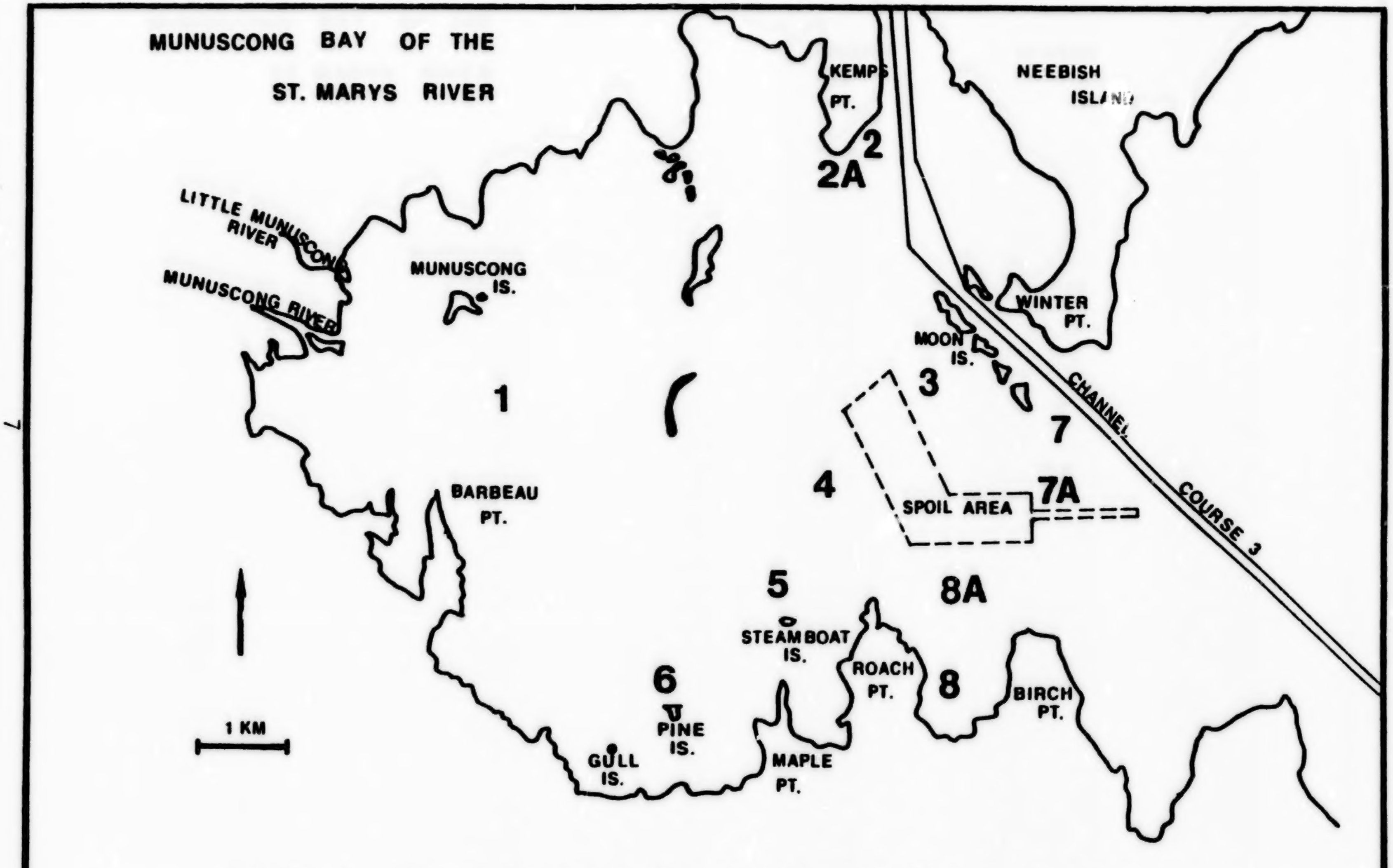

Figure 3. Map of Munuscong Bay showing generalized sampling stations 1-8 and reference landmarks.

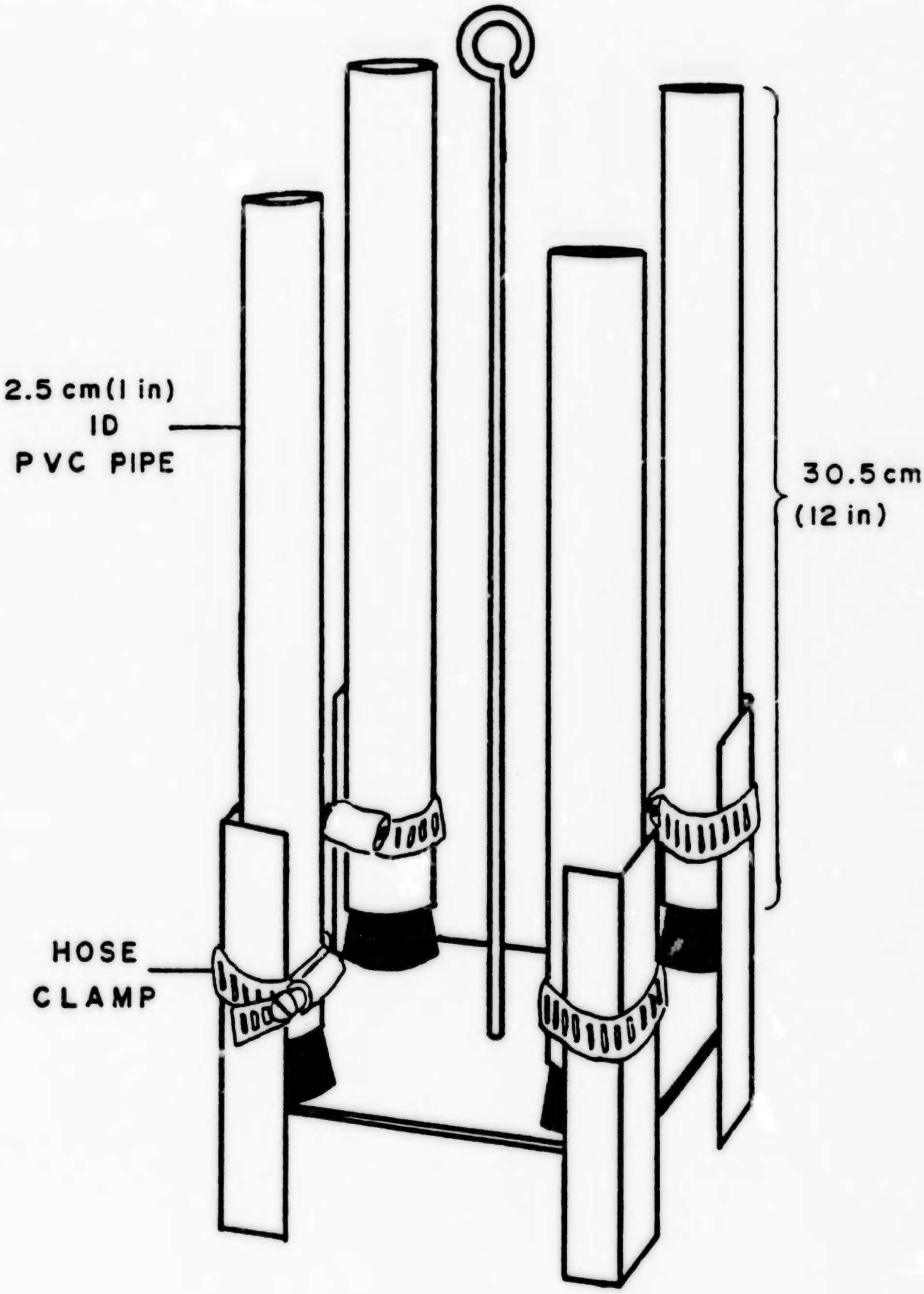

Figure 4. Diagram of the sediment trap device used to estimate sedimentation in Munuscong Bay.

Table 1. Description of 1984 winter sedimentation sampling stations and exposure periods in Munuscong Bay, St. Marys River.

Station	Depth (m)	Ice Thickness (m) On Date Set	Exposure Period First	Exposure Period Second
1	1.7	0.4	Jan11-Feb14	Jan11-Mar14
2	2.5	0.3	Jan11-Feb13	Jan11-Mar14
2A	6.5	0.2	Jan11-Feb13	-
3	3.0	0.3	Jan11-Feb13	Jan11-Mar14
4	2.3	0.4	Jan11-Feb13	Jan11-Mar14
5	1.8	0.4	Jan11-Feb13	Jan11-Mar14
7	1.8	0.4	Jan17-Feb14	Jan17-Mar14
7A	12.5	0.4	Jan17-Feb14	Jan17-Mar14
8	1.6	0.4	Jan17-Feb14	Jan17-Mar14
8A	3.3	0.3	Jan17-Feb14	Jan17-Mar14

Sedimentation was calculated for a mean weight of sediment deposited in each tube for each site. Sediment accumulation for the second exposure period was estimated as the difference in mean weight of sediments for the second and the first exposure periods. Sediment collection rate (mg/d) was determined by dividing the mean sediment weight by the exposure time (in days) of each set. Sedimentation rates per unit area ($mg/d/m^2$) were calculated by dividing the sediment collection rate by the area of a collection cylinder ($5.067x10^{-4} m^2$).

Sediment size-range distributions were determined by the decantation method (U.S. Army Engineer School 1977). Only five stations (1,2,3,5,7A) had ample sediment to complete the decantation process. These previously filtered and dried sediment samples were soaked for 48 hours in closed containers with 0.41 g of sodium hexametaphosphate (brand name "Calgon") and 10 ml distilled water. Each sample was then brought up to a total volume of 100 ml with 16 °C distilled water. Samples were vigorously shaken, allowed to settle over four minutes and then quickly subsampled with a removal of 20 ml of solution by pipette. The procedure was repeated with a settling time of 10 seconds to sample particles less than 60 u in size. Based on Twenhofel (1950), the first decantation was assumed to remove particles of less than 10 u diameter. The 10 u and 60 u divisions in sizes were used because 1) 10 u differentiates silts from clays and 2) previous sediment settling experiments (Liston et al. 1983) have indicated most sediments are less than 69 u in size. Larger particles such as sand and coarse sands were not common in the study area.

Samples of each size range were dried at 100 °C for 24 hours, cooled, and weighed to the nearest tenth of a milligram. Sediment weights were determined by subtraction of the pre-weighed container and Calgon (assumed 20% of total Calgon input). The proportion of volume decanted was also applied to weight of sediment decanted to determine the sediment weight for each specified size range.

Percent composition of the two size ranges (<10 u and < 60 u) was determined from the weight of each fraction and total weight of sediment used in the decantation process. Weight of particles less than 60 u was corrected for the previously removed particles of less than 10 u. Subtracting the percentage of sediments in each size fraction yielded the percent weight of sediment between 10 and 60 u. Total weight of sediment was divided by the weight of remaining sediment to determine the percent composition of particles greater than 60 u.

Sediment particle sizes were determined to allow back calculation of the suspended sediment concentration (mg/l) and particle settling rate (cm/d) by the following:

$$\text{Sediment load} = \frac{\text{Sedimentation rate (x10)}}{\text{Particle settling rate}}$$

Settling rates for particles 2 u, 10 u, and 60 u in diameter corrected to water at 0 °C, were used to determine suspended concentration for sediments in the <10 u, 10 u to 60 u, and > 60 u size ranges, respectively, to represent potential maximum suspended sediment. Calculated suspended sediment concentrations for all three size ranges were summed to give a total suspended sediment concentration.

BENTHIC MACROINVERTEBRATES

Field Methods

Benthic macroinvertebrate samples were collected during 1 to 4 May, 1984, using a standard PONAR grab in open water and an Ekman grab in areas near emergent vegetation. The PONAR grab encloses an area of 484 cm^2 and the Ekman grab encloses 232 cm^2 (Wildlife Supply Co., Saginaw, Michigan). Ekman grab samples were taken at 4 sites (stations E1, E2, E6, E8) and PONAR grabs were taken at 10 sites (all stations except 6) in Munuscong Bay (Figure 5). Six replicate grabs were taken at each Ekman sampling site, and triplicate samples were taken with the PONAR grab. A total of 24 Ekman and 30 PONAR grab samples were thus collected.

Laboratory Methods

Benthos samples were transported back to the laboratory for processing and analysis. Each sample was rinsed through a standard no. 30 sieve (600 u aperture) and a 10% subsample of the resultant slurry was passed through a 250 u sieve. All organisms retained on these sieves were sorted over light tables and identified using stereo-zoom microscopes (7-40 x and 20-80 x). Taxonomic references included Hilsenhoff (1975), Holsinger (1976), Merrit and Cummins (1978), Penak (1978), and Wiggins (1977).

Data Presentation

The resulting benthos data were transformed to the number of organisms per square meter of substrate. Based on an enclosed area of 484 cm^2, PONAR grab samples had a multiplication factor of 20.7. Counts from Ekman grab samples were multiplied by 43.3 to convert to numbers per square meter.

FISH LARVAE

Field Collecting

Larval fish were sampled at eight stations in Munuscong Bay including stations 1,2,3,4,5,6,7, and 8 (Figure 6). Samples were taken at night every two weeks from ice-out (late April) through August (Appendix C). Due to the wide range of habitats sampled, a variety of nets were deployed as described in detail below. All nets were made of 351 u mesh nitex and were equipped with a General Oceanics flowmeter (model no. 2030) offset one-third in the net aperture to measure the volume of water filtered. After deployment all nets were washed down and their contents condensed and preserved in 10% formalin.

Channel and Deep Water Sampling

Duplicate stepped-oblique tows of a bridled 1.0 m nitex conical plankton net (1:3 mouth-to-length ratio) were taken in the shipping channel at stations

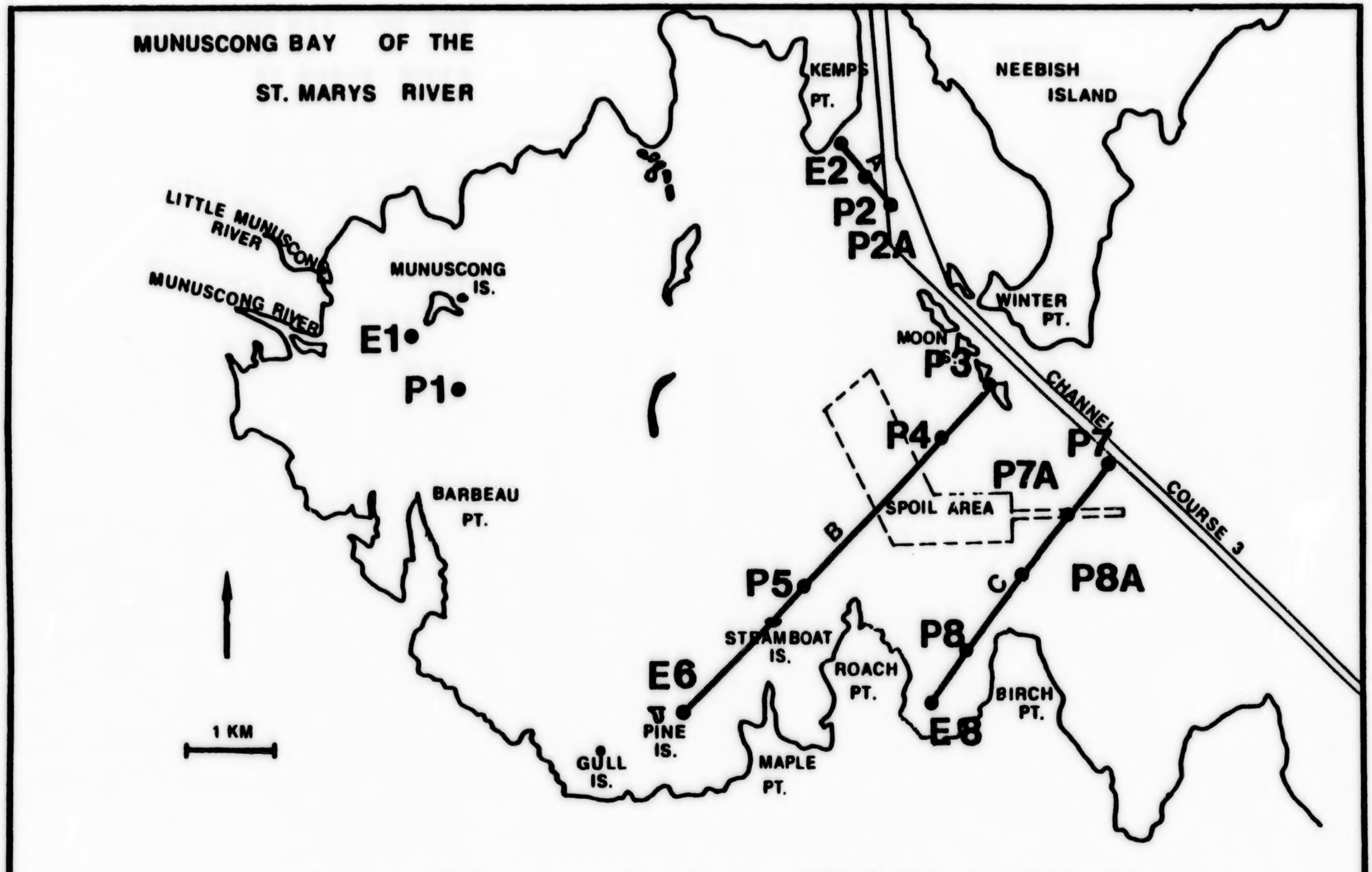

Figure 5. Map of Munuscong Bay showing PONAR (P1, P2, P2A, P3, P4, P5, P7, P7A, P8, P8A) and Ekman dredge (E1,E2,E6,E8) sampling sites.

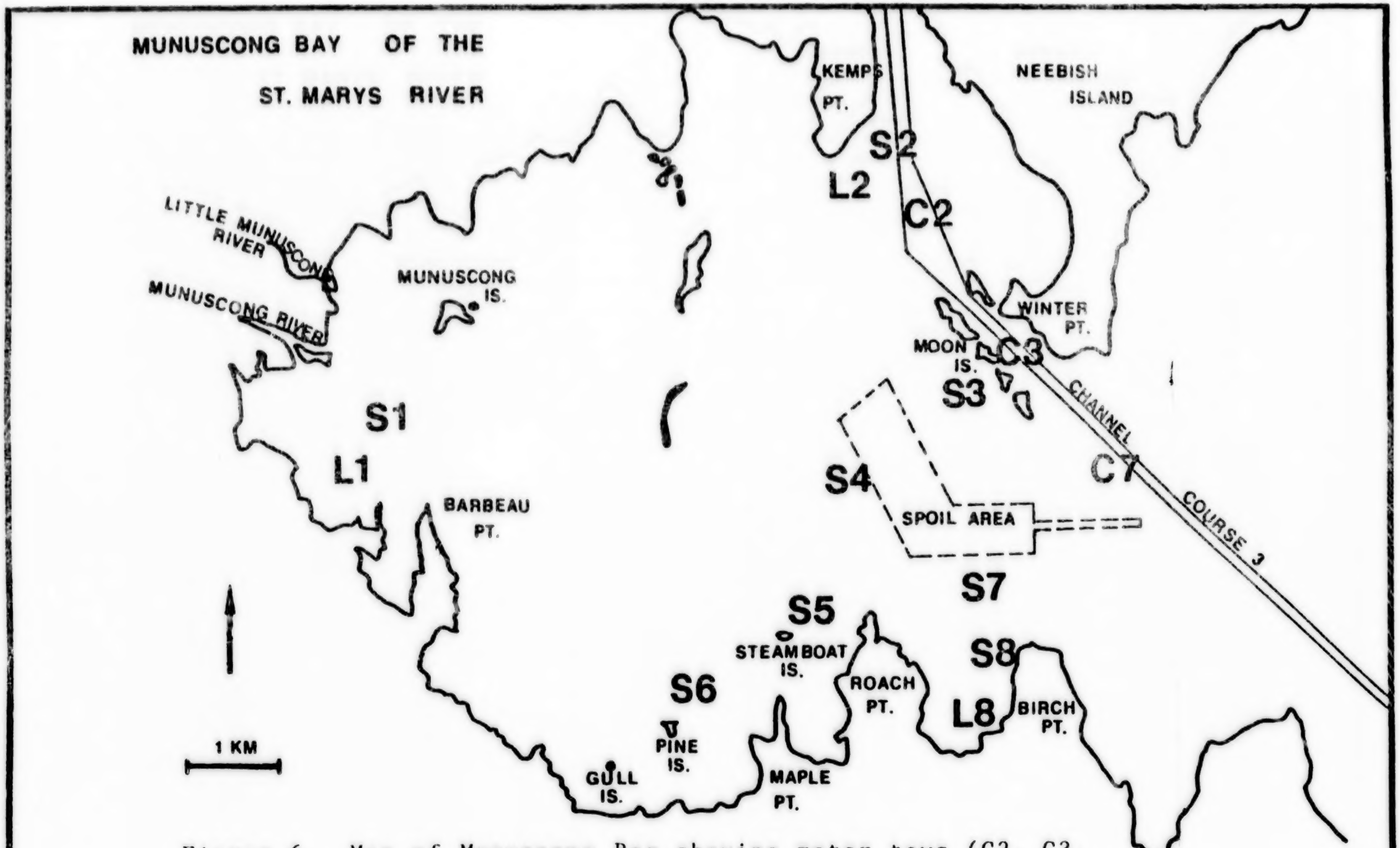

Figure 6. Map of Munuscong Bay showing meter tows (C2, C3, C7), push net (S1-S8), and pull net (L1, L2, L8) sampling sites in channels, nearshore, and littoral areas, respectively.

C2 and C3 and at a deep, off-channel site near the spoil area in eastern Munuscong Bay (station C7; Figure 6). The net was towed off the bow of the boat while backing into the current. Each tow spanned 5 minutes, with the net towed approximately 1.5 minutes at each of 3 depths: near bottom, mid-depth, and near the surface. For bottom and mid-depth tows, 18 and 9 m of line, respectively, were let out, and engine speed was maintained to retain a towing angle between 65 and 67 degrees. A Wildco line/cable clinometer was used to determine the angle of the tow and thus enabled calculation of the towing depth. A total of 52 oblique tow samples were taken during 1984, filtering an average of 103 m^3 per tow (Table 2).

Shallow, Open Water Sampling

A 0.5 m push net (after Tarplee et al. 1979) was used to collect larval fish along the edge of the emergent macrophyte beds at all stations (Figure 6). The nets were mounted at the bow of a small craft and pushed for 5 minutes near the surface of water usually 1-2 m deep. A total of 139 push net samples were taken in 1984 filtering an average of 44 m^3 per sample (Table 2).

Shallow Littoral Sampling

A pull net was designed and constructed to collect larval fish in the shallow, littoral zone of Munuscong Bay. This gear was a modified sheet metal snow scoop, with the back panel removed and the handle reversed (Liston et al. 1983). A 0.5 m plankton net was attached to the back of this scoop forming a rectangular mouth area of 1,134 cm^2 (21 x 54 cm). The net was pulled parallel to the shore by two wading operators. Pull net samples were taken in water of less than 1 m at stations L1, L2, and L8 (Table 6). A total of 54 pull net transects were taken in 1984 sampling an average water volume of 1.9 m^3 per sample (Table 2).

Laboratory

Samples were sorted in clear pyrex pans under a lighted magnifying lens over light tables of both light and dark backgrounds. Eggs and larvae were counted, removed, and stored in modified Davidson's solution (Lam and Roff 1977). Fish larvae were identified with a Bausch and Lomb binocular microscope equipped with a polarizing filter. Specimens too damaged to permit proper identification were designated unidentifiable. Total length of larvae was measured to the nearest 0.1 mm using an ocular micrometer. A maximum of 10 individuals were measured as subsamples of numerous species.

Data Presentation

The volume of water filtered during each 0.5 m and 1.0 m net tow was determined by first calculating the distance of the tow:

$$\text{Distance (m)} = \frac{\text{(flowmeter count difference) x rotor constant}}{999{,}999}$$

Table 2. Descriptive statistics of larval fish samples in the littoral (pull net), nearshore (push net), and channel/deepwater zones (tow net) of Munuscong Bay, 1984.

	Littoral	Nearshore	Channel Deepwater	Totals
Samples	54	139	52	245
Vol.Strained (m^3)	102.5	6,154.9	5,363.4	11,620.8
No. Larvae collected	802	4,840	1,089	6,731
Overall density (no/100 m^3)	782.4	78.6	20.3	57.9

where the rotor constant, as supplied by the manufacturer, is 26,873 for the standard rotor and 51,020 for the low velocity rotor. The volume is then calculated as follows:

$$\text{Volume } (m^3) = \frac{(\text{area of net mouth}) \text{ x distance}}{4}$$

$$= 3.14 \text{ (net diameter)}^2 \text{ X distance}$$
$$= 0.7850 \text{ X distance (for 1.0 m net)}$$
$$= 0.1963 \text{ X distance (for 0.5 m net)}$$
$$= 0.1134 \text{ X distance (for pull net)}$$

The volume of water filtered and the number of fish larvae collected were used to estimate the density, or the number of individuals per 100 cubic meters. Density was calculated by multiplying the number of organisms by 100 and dividing by the volume filtered.

JUVENILE AND ADULT FISH

Trawls

A total of 32 trawls were taken in Munuscong Bay during 1984. Sampling dates were approximately monthly, May through August (Appendix D). Bottom trawl samples were taken at eight sites in Munuscong Bay (Figure 7). Bottom trawl samples were collected at night with a semi-balloon otter trawl having a 4.9 m head rope, 38 mm stretched mesh body, and 3 mm bar mesh cod end liner. Each sample consisted of towing the net for 5 minutes behind a boat powered by outboard engines.

Fish samples were taken to the laboratory, kept on ice overnight, and processed the next morning. Processing consisted of recording the total number and total weight of each species captured, and recording length, weight, and sex data for individuals. Scale, otolith or fin ray samples were taken for later age determinations.

Small-Mesh Trap Nets

Small-mesh trap nets were deployed in shallow-water littoral areas where the use of large-mesh trap nets was not feasible. A total of 18 sets sampled fishes at eight Munuscong Bay stations (Figure 8). Nine sets were completed in both July and August with some replication of sample sites (Appendix A.5). Nets were constructed of 6.35 mm bar mesh nylon with 15.2 X 1 m leads, 2.2 X 1 m wings, a 1 m pot, and a single heart (Liston et al. 1980). Nets were set perpendicular to the shore in water less than 1.2 m deep. The net lead was anchored or staked as near shore as possible. All nets were set in the morning and pulled 24 hours later. Large fish were processed in the field and released. Smaller fish were transported back to the laboratory for proper identification and enumeration.

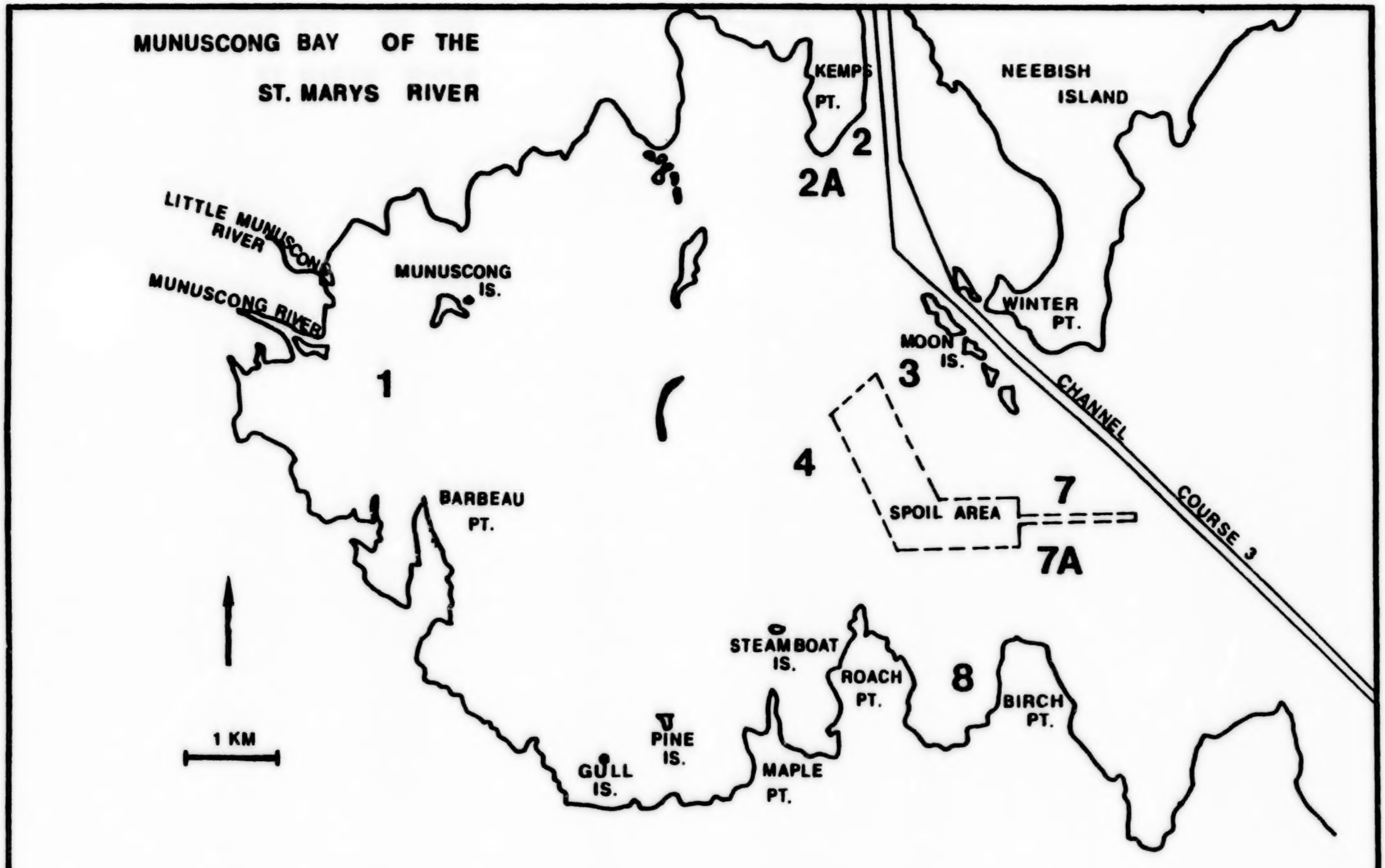

Figure 7. Map of Munuscong Bay showing bottom trawl sampling sites.

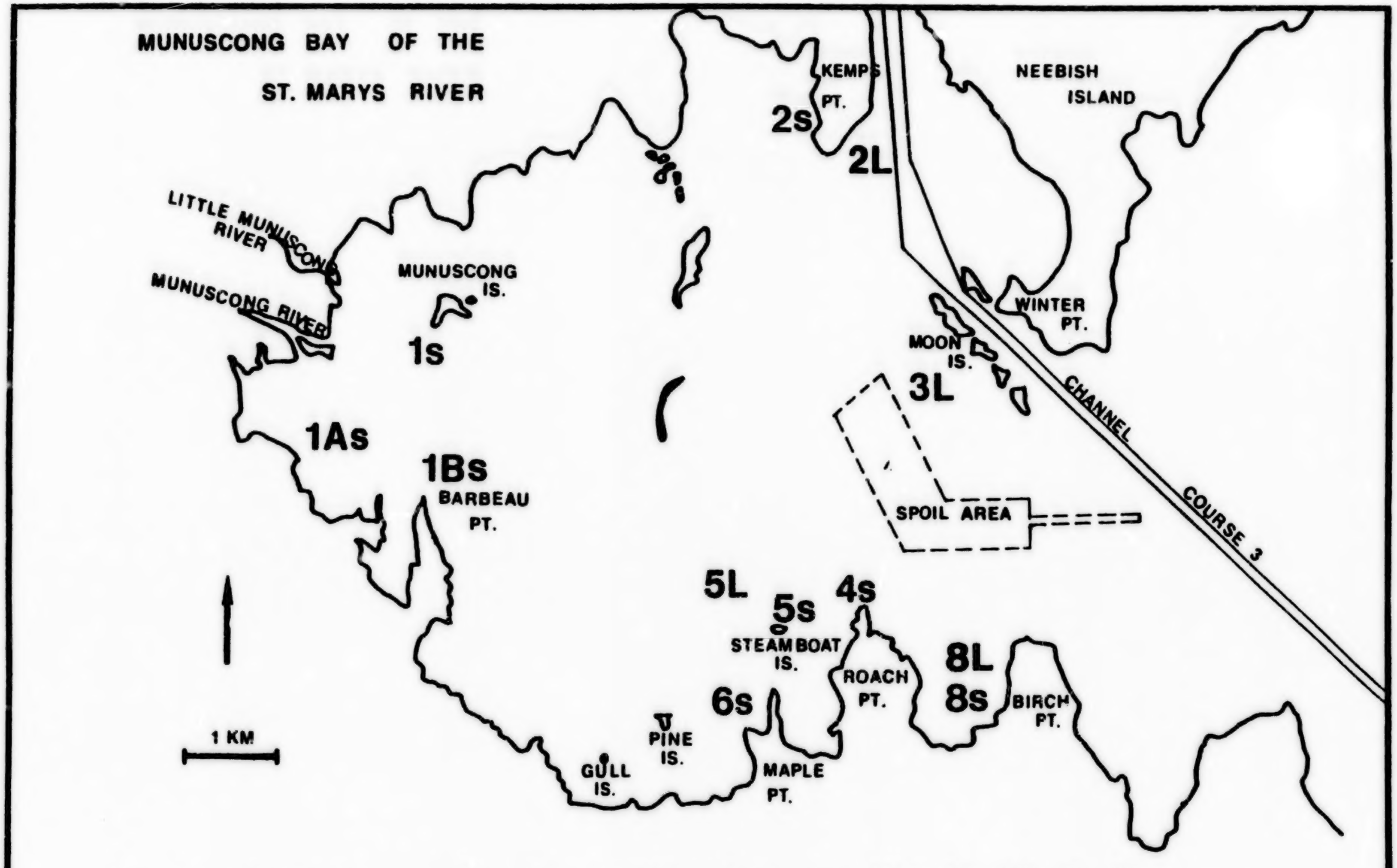

Figure 8. Map of Munuscong Bay showing small-mesh trap net (1AS, 1S, 1BS, 2S, 4S, 5S, 6S, 8S) and large mesh trap net (2L, 3L, 5L, 8L) sampling sites.

Large-Mesh Trap Nets

The large trap nets fished in Munuscong Bay were the same as those used previously in the St. Marys River (Liston et al. 1985), and were of the following dimensions: pots were made of 5.1 cm stretched nylon mesh (no. 15 twine) 1.2 m high, 1.8 m wide and 3.1 m long; hearts extended 4.6 m from the pot and were made of 5.1 cm stretched nylon mesh; leads were 91.2 m long and were made of 10.2 cm stretch nylon mesh (no. 9 twine).

Large-mesh trap nets were set monthly from April through September at 4 stations (2L, 3L,5L,and 8L; Figure 8). Effort was standardized at 48 hr, with all nets checked at 24 hours. In the event of a large catch at 24 hours, some fish were measured, tagged and promptly released to reduce mortalities and the processing volume of the following day. Numbers and total length (mm) of all fish captured in the pot were recorded for each set. Weights (g) were taken when weather conditions permitted. Some fish species (ie. walleye, yellow perch, channel catfish, smallmouth bass, rock bass, northern pike, brown bullhead, etc.) were tagged with orange-spaghetti floy tags, except walleye which were tagged with a National Band jaw tag. Sex determinations were restricted to periods of the incidence of ripe individuals.

RESULTS AND DISCUSSION

PHYSICAL AND CHEMICAL ASPECTS

Water Temperature

Water temperatures steadily increased from 3-7 °C in April to peaks of 20-24 °C in August, 1984 (Appendix A). Temperatures began to decline in late August through early September. Throughout the sample season, offshore temperatures were several degrees cooler than temperatures at the nearshore and macrophyte edge (Figure 9). This pattern was also evident across stations. Near the tributaries (1) and along the southern shore (6 and 8) temperatures were as much as 5 °C warmer than mid bay (4) and near channel (2,3 and 7) stations (Figure 10). Similar results were also seen throughout the St. Marys system in previous studies (Liston et al. 1985). Water temperatures are of upmost importance to the functioning of many aquatic organisms (Beltz et al. 1974). This nearshore/offshore temperature difference may play an important role in the growth of aquatic macrophytes and the abundance of phytoplankton, associated zooplankton, benthic invertebrates, and fish.

Dissolved Oxygen

In general, dissolved oxygen declined over the sample season. Highest dissolved oxygen levels were measured in late April ranging from 9 to 13 mg/l (Appendix A). Dissolved oxygen readings gradually dropped to 7 to 10 mg/l in late August. Rising water temperatures and nighttime biological respiration rates may explain this pattern. A similar decline was documented throughout the St. Marys River system (Liston et al. 1985). Offshore (1.0 m tows) and mid bay (4) stations maintained higher oxygen levels, perhaps due to lower temperatures and less respiration activity (Figure 11). Inshore stations were as much as 3 mg/l lower in oxygen than the macrophyte edge or offshore stations (Figure 12). Mid bay, channel and southern shore stations were comparable in D.O. but 1-3 mg/l higher than the tributary station (1). Of course, dissolved oxygen is crucial for the well-being of a number of aquatic organisims, particularly fish in the early larval stages. Dissolved oxygen levels were always above the 5.0 mg/l EPA recommended level for maintaining healthy fish populations (Brungs 1977).

Turbidity

Water turbidities ranged from 1.7 to 86 NTU with much variation across sampling dates and stations (Appendix A). Highest turbidities were generally recorded ($\bar{x} = 31$ NTU) in April, with lowest values measured in mid June ($\bar{x} = 8$ NTU). Only the southern shore achieved a peak turbidity in July, perhaps signifying a storm event with winds out of the northwest. Turbidity readings differed greatly between successive sample dates but without any clear patterns

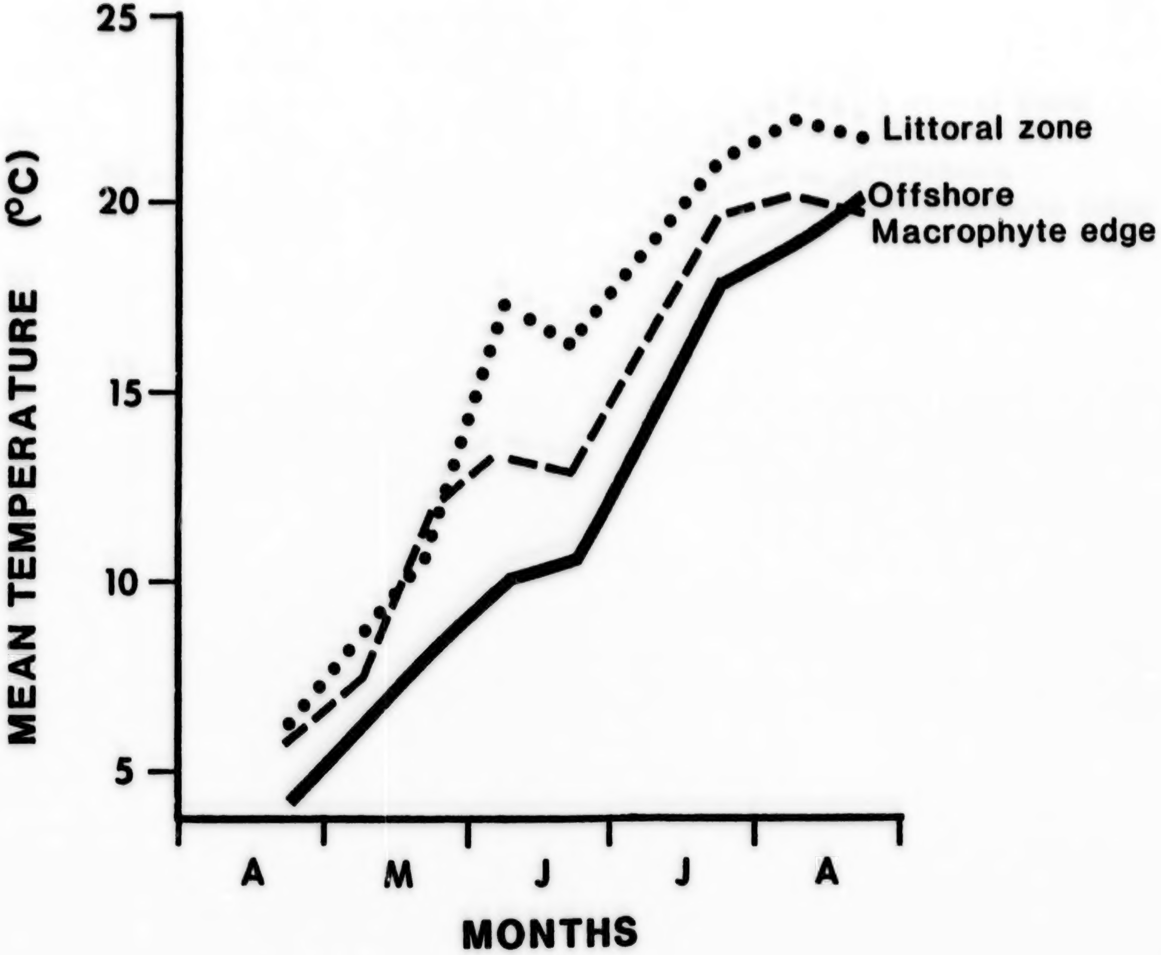

Figure 9. Water temperature of the offshore (tow net), macrophyte edge (push net), and shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.

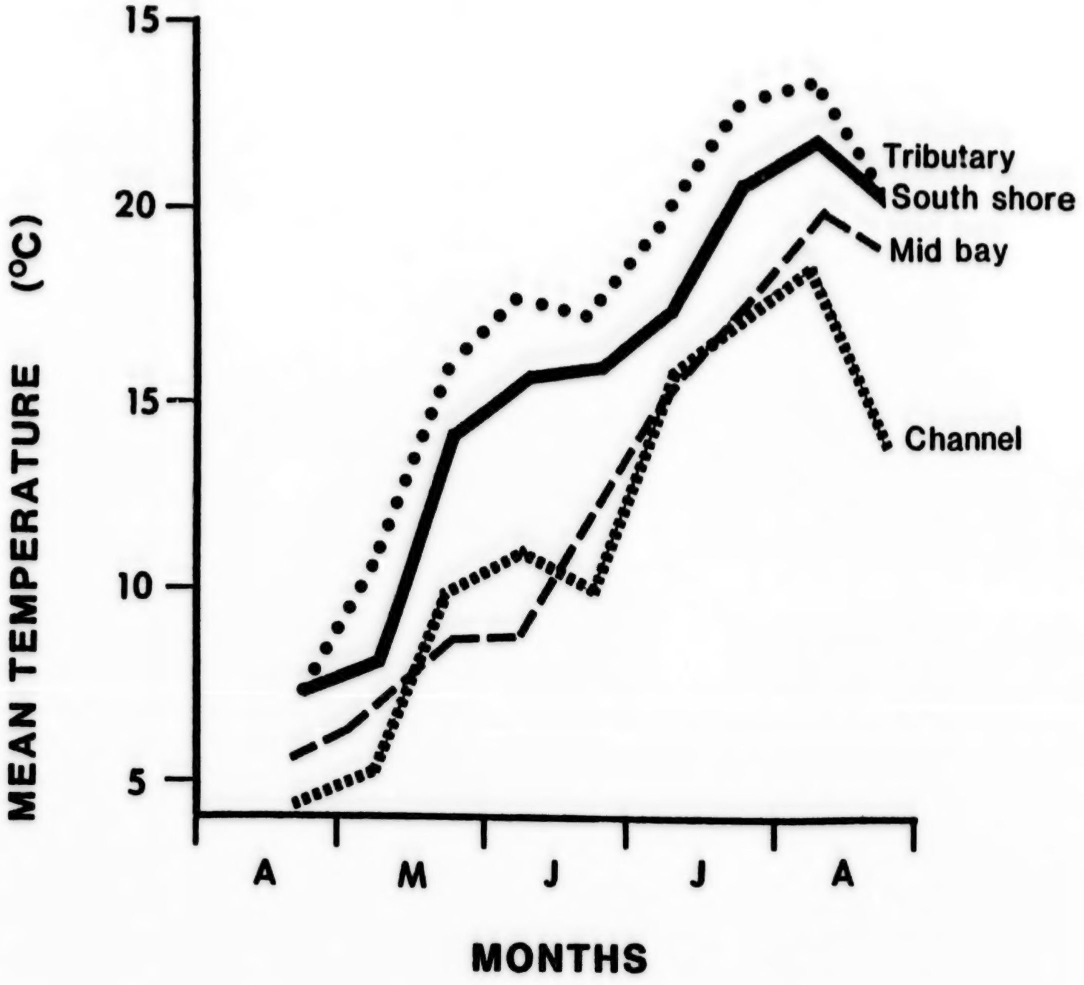

Figure 10. Average water temperatures at larval fish sampling stations near the channel (2,3,7), mid bay (4), southern shore (6,8), and tributary inflow (1) of Munuscong Bay, 1984.

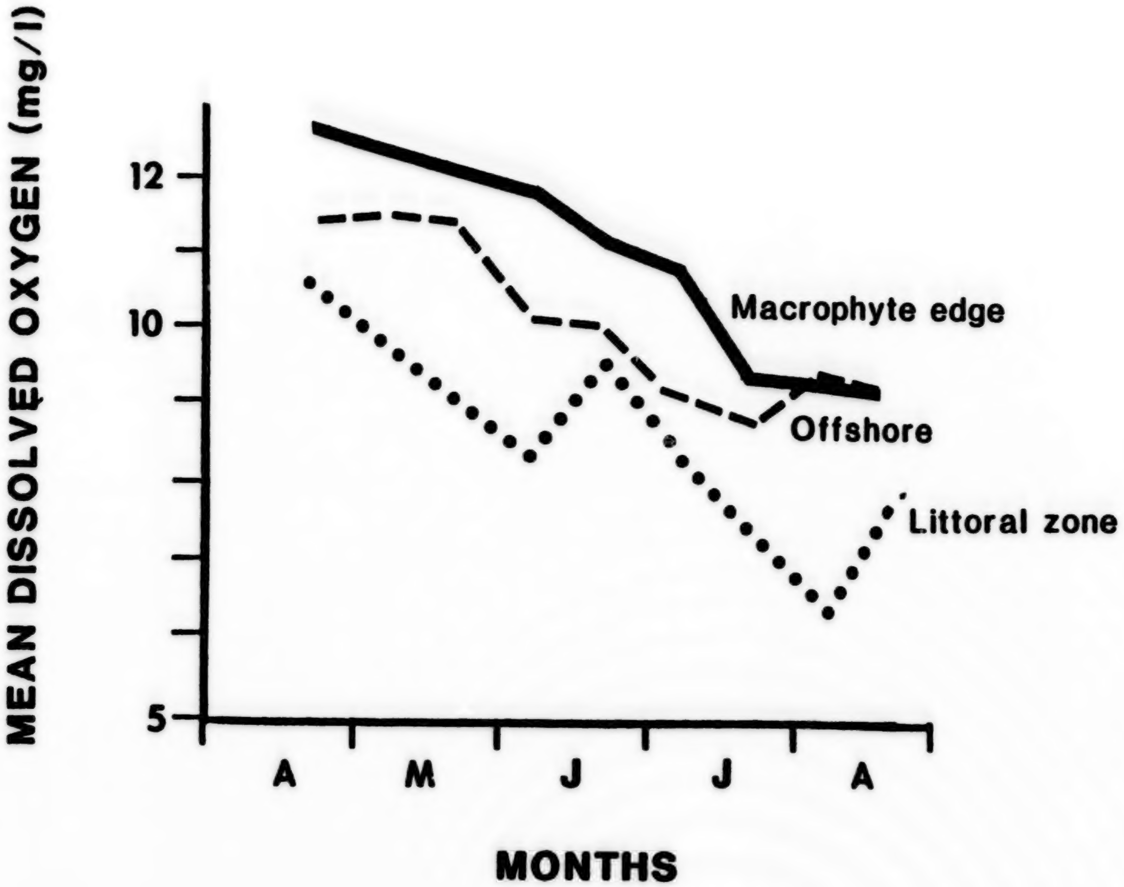

Figure 11. Dissolved oxygen at offshore (tow net), macrophyte edge (push net), shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.

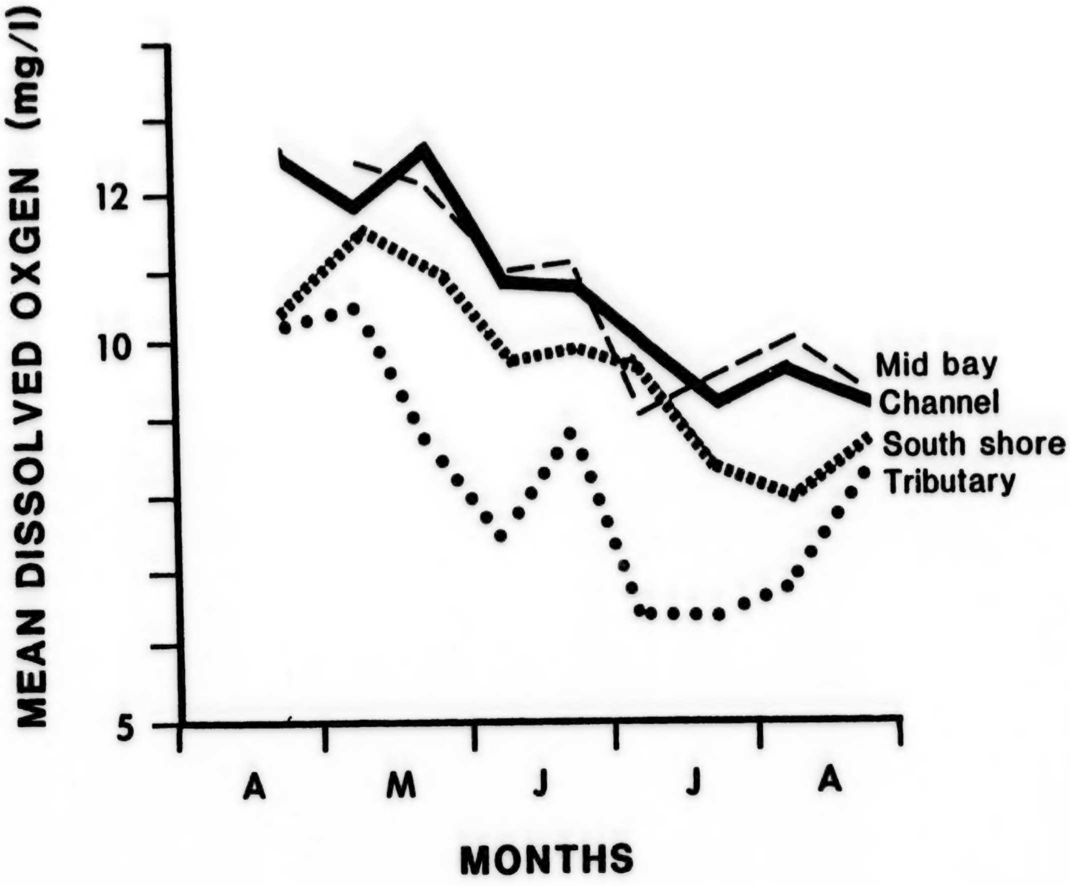

Figure 12. Average dissolved oxygen at larval fish sampling stations near the channel (2,3,7), mid bay (4), southern shore (6,3), and tributary inflow (1) in Munuscong Bay, 1984.

of temporal change across stations (Figure 13). In general, nearshore stations were much more turbid than channel stations. Moreover, station 1 exhibited the highest turbidity perhaps as a result of the tributary inputs of the Little Munuscong and Munuscong Rivers (Figures 2 and 14). The southern shore was also high in turbidity throughout the sample season. Similar patterns of increased turbidity near tributary outflow and in exposed shallow areas was documented in the St. Marys River in previous studies (Liston et al. 1985).

Turbidity appears to be the result of resuspension of fine clays common to the St. Marys River system. In Munuscong Bay, turbidity seemed to be associated with wave action in the shallows and direct inputs from tributaries. The navigation channels may not be a major input of turbid water. During months of ice-free vessel passage Liston et al. (1985) demonstrated that mean turbidities of the channels ranged from 1.3 to 3.7 NTU, values far below those considered detrimental to the fishery (Alabaster and Lloyd 1980). It must be remembered that channel inputs are an amalgamation of all upstream sources, and not just the result of navigation activities. Morever, other inputs such as the Little Munuscong, Munuscong, and Gogomain Rivers have been shown to carry high levels of turbidity, particularly in spring. However, it is likely that some increase in turbidity would be observed during extended winter shipping (Poe et al. 1979; Liston et al. 1985).

Though high levels of suspended materials can directly impact invertebrates and fish by fouling gill mechanisms, which can affect circulation, respiration, excretion, and salt balance (Ellis 1937; Cordone and Kelly 1961), or by causing ingestion of sediment by small fish (Shenk et al. 1974; Peddicord and McFarland 1978), such high levels are not expected to occur in the St. Marys River system with or without extended season shipping. Such effects may not occur until turbidities reach 500 NTU or higher (USFWS 1970). Turbidity effects on eggs and larvae are not well documented. However, researchers have found no significant effects of suspended sediment loads up to 500 mg/l on the hatching success (Schubel and Wang 1973), growth, and survival of larval fishes (Swenson and Matson 1976).

Indirect effects of turbidity are perhaps more relevant to the Munuscong Bay. Possible effects include lower feeding success for visual predatory fishes (Wilber 1971), reduced oxygen levels (Morton 1977), and the disruption of normal social or distributional behavior (Stern and Stickle 1978). Waters with more than 25 mg/l suspended sediment load are considered undesirable for quality fisheries (Alabaster and Lloyd 1980). Moreover, slight increases in turbidity can limit the outer depths of submergent macrophytes, presumably due to poor light penetration (Liston et al. 1985).

Winter Sedimentation

Sediment collection ranged from 1.2 to 128.0 mg per sample tube in the first exposure period from 11-17 January through 13-14 February (Table 3). Mean collected sediment weights were from 2 to 10 times greater for the second exposure period, extending through 14 March. Individual sediment weights ranged from 4.4 to 287.6 mg over the extended sampling period. Calculated sediment collection rates ranged from 0.06 to 4.1 mg/d with mean values of 0.88 and 0.96 mg/d in the first and second periods, respectively (Table 4). Likewise,

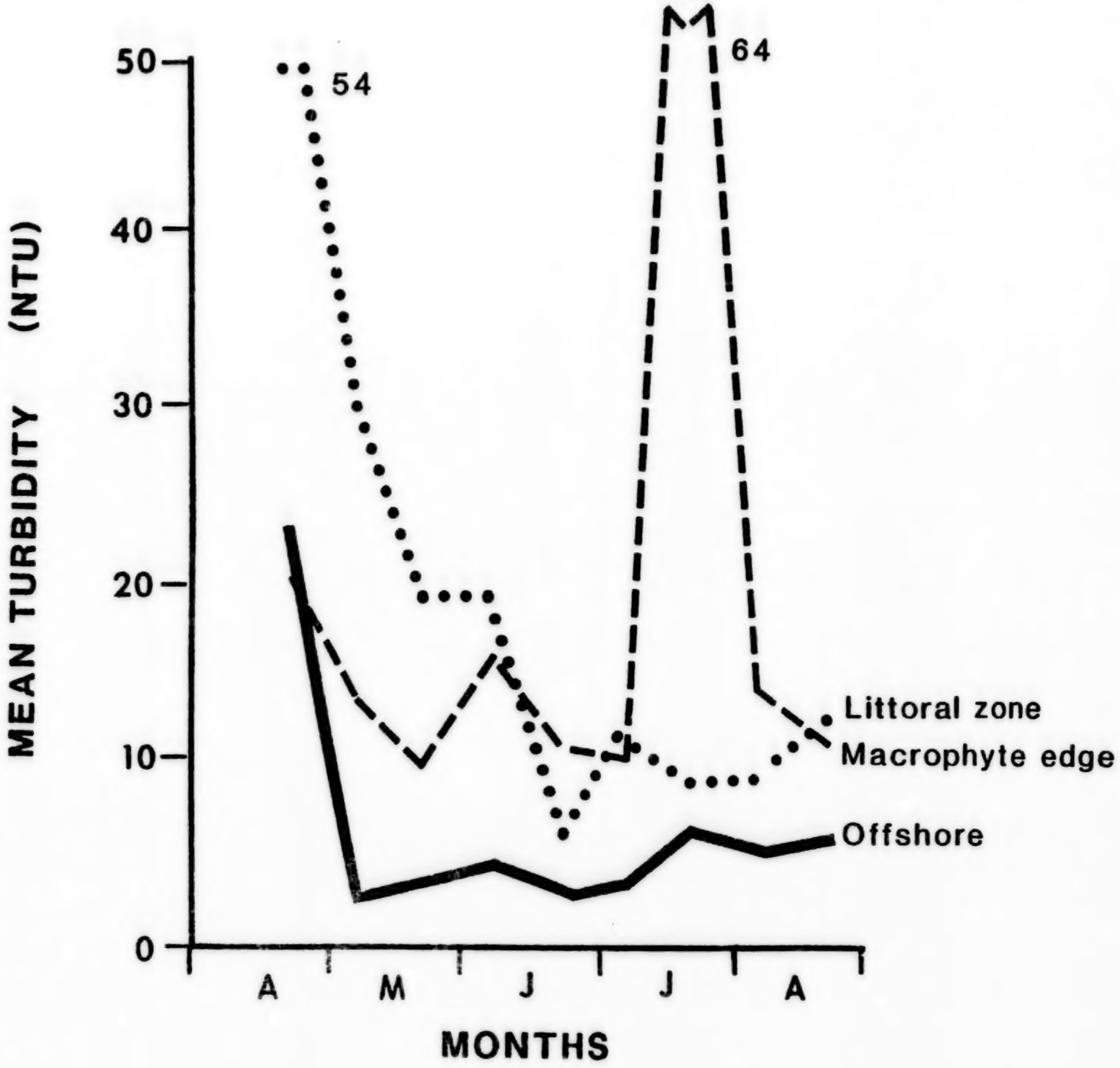

Figure 13. Turbidity at offshore (tow net), macrophyte edge (push net), and shallow littoral (pull net) sites as averaged across stations and measured by night during larval fish sampling in Munuscong Bay, 1984.

BLANK PAGE

BLANK PAGE

BLANK PAGE

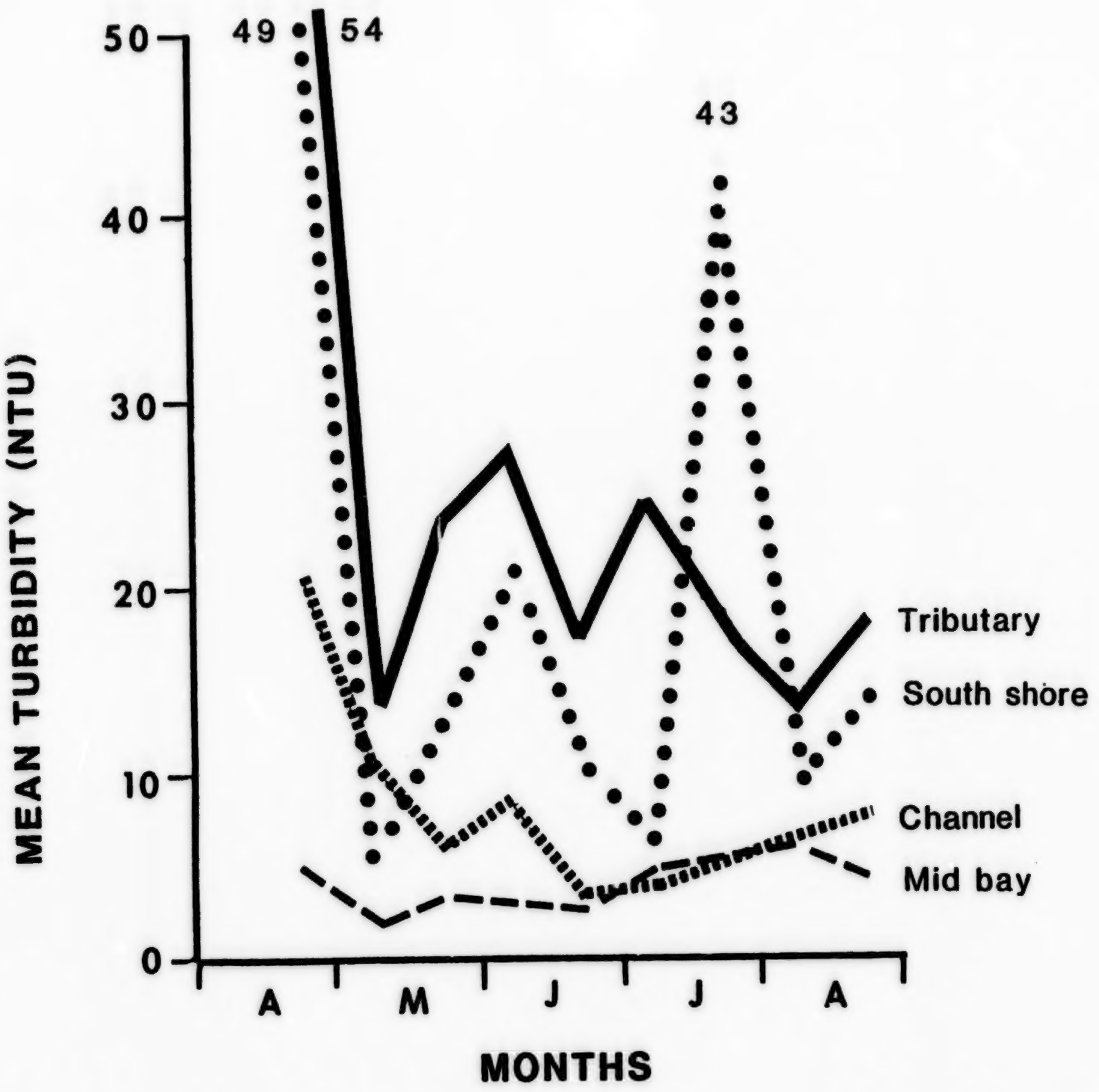

Figure 14. Average turbidity at the larval fish sampling stations near the channel (2,3,7), mid bay (4), southern shore (6,8), and tributary inflow (1) in Munuscong BAy, 1984.

27

Table 3. Range, mean, and standard deviation for weights of sediment collected during winter in Munuscong Bay, St. Marys River, 1984.

	Weight (mg) of sediments collected during first exposure period			Weight (mg) of sediments collected during second exposure period		
Station	Range	Mean	SD	Range	Mean	SD
1	39.4 - 65.7	48.6	11.7	70.5 - 80.7	77.5	4.8
2	121.6 - 128.0	126.0	3.0	253.3 - 287.6	267.2	15.4
2A	55.4 - 75.0	62.6	9.3	-	-	-
3	2.2 - 2.6	2.4	0.2	22.3 - 24.1	23.4	0.8
4	5.7 - 7.3	6.2	0.7	7.0 - 9.5	8.3	1.0
5	16.4 - 8.8	17.6	1.0	45.1 - 56.8	48.6	5.5
7	1.2 - 2.3	1.8	0.6	4.4 - 5.8	5.1	0.7
7A	45.7 - 54.2	49.7	3.5	88.5 - 92.9	91.2	1.9
8	1.9 - 2.7	2.3	0.4	5.6 - 9.6	6.8	1.9
8A	2.0 - 2.2	2.1	0.1	7.3 - 9.1	8.2	0.9

Table 4. Sediment collection rate and sedimentation rate per unit area during winter in Munuscong Bay, St. Marys River, 1984.

	Sediment collection rate ($mg\ day^{-1}$)		Sedimentation rate ($mg\ day^{-1}\ m^{-2}$)	
Station	1st exposure	2nd exposure	1st exposure	2nd exposure
1	1.39	1.21	2,744.9	2,389.4
2	3.71	4.18	7,326.2	8,254.3
2A	1.84	-	3,633.5	-
3	0.08	0.40	163.5	795.8
4	0.21	0.14	422.6	282.4
5	0.60	0.84	1,198.7	1,654.8
7	0.06	0.09	122.6	173.6
7A	1.71	1.57	3,376.8	3,100.3
8	0.08	0.12	156.6	231.0
8A	0.07	0.14	143.0	278.4

sedimentation rates per unit area were on the average 10 percent greater during the second period (Table 5). Apparently, a slightly higher sediment load occurred in March than in February with most notable increases at the near channel stations 2 and 3 (Table 4; Figure 3).

Indeed, sedimentation rates differed greatly between sampling stations. Highest values were measured at station 2, near the downbound navigation channel. Sedimentation rates were 7,326 and 8,254 mg day^{-1} m^{-2} for the first and second exposure period, respectively (Table 4). It was not apparent however, that other stations near the navigation channel were also areas of high sediment loading. In fact, stations 3 and 7 were relatively low with first exposure sedimentation rates of 163.5 and 122.6 mg day^{-1}m^{-2}, respectively. The Moon Islands may shelter stations 3 and 7 from the sediment loading of the navigation channel. Station 7A is located in a deep hole and may serve as a depositional area for some channel sediments as indicated by relatively high sedimentation rate values of 3,377 and 3,100 mg day^{-1} m^{-2} for first and second exposure periods respectively (Table 4). Station 8 was lower in sedimentation at 143.0 and 156.6 mg day^{-1} m^{-2} at replicate sites. Station 1, however, was relatively high in sediment loading perhaps due to its extensive shallow waters, and inputs from nearby Little Munuscong and Munuscong Rivers (Figure 3).

Sediments collected in the traps were predominantly between 10 to 60 u in size (Table 6). Sediments greater than 60 u comprised the second greatest fraction, and when combined with those between 10 to 60 u, averaged more than 90% of the total weight of the collected sediments. Sediments less than 10 u ranged from none detected at station 3 to 13.9% total weight at station 1. Apparently, the fine silts of less than 10 u are not deposited near the navigation channel but are prevalent in sheltered bays (station 5) and basins (station 7A) or at regions of tributary inflow (station 1).

Sedimentation in Munuscong Bay was largely fine silts (10-60 u) and course silts and fine sands (> 60) while particles less than 10 u in size proved the minority of deposited materials. Maximum suspended sediment load as calculated from the sedimentation rates of major particle sizes ranged from 0.1 to 1.5 mg/l for the five sites in Munuscong Bay (Table 5). Suspended sediment concentrations were largely determined by the small (<10 u) sized particles which take longer to settle out. Stations with high concentrates of silt such as 1, 5, and 7 A were thus also more susceptible to the continued resuspension of sediments leading to increased turbidity. This correlates with turbidity data and illustrates a relationship of turbidity and sediment loading. Previous work on the St. Marys system has revealed that stations displaying higher sedimentation rates were not necessarily characterized by increased suspended sediment (Liston et al. 1985). Turbidity is related to the suspension of specific types of sediment (i.e. fine silts and clays).

Munuscong Bay sedimentation followed patterns similar to those previously observed along the St. Marys River. Sedimentation rates were slightly higher than values collected in 1982 and 1983 (Liston et al. 1985) suggesting increasing turbidities. However, sedimentation values were comparable to those recorded in Lake George, a shallow open-water system which unlike Munuscong Bay was not open to commercial navigation (Liston et al. 1983).

Table 5. Maximum calculated suspended sediment concentration measured during 1984 in Munuscong Bay, St. Marys River.

Station	particle size range(u)	Sediment Collected weight (mg)	rate ($mg/day/cm^2$)	Maximum Calculated Suspended Sediment Concentration mg/1
1	<10	10.8	0.03	1.0
	10-60	40.8	0.13	0.2
	>60	25.9	0.08	*
	Total	77.5		1.2
2	<10	5.0	0.02	0.7
	10-60	136.3	0.42	0.5
	>60	125.9	0.39	*
	Total	267.2		1.2
3	<10	0.0	0.0	*
	10-60	16.5	0.06	0.1
	>60	6.9	0.02	*
	Total	23.4		0.1
5	<10	5.6	0.02	0.7
	10-60	37.0	0.13	0.2
	>60	6.0	0.02	*
	Total	48.6		0.9
7A	<10	11.5	0.04	1.3
	10-60	53.5	0.18	0.2
	>60	26.2	0.09	*
	Total	91.2		1.5

* less than 0.1

Table 6. Percent composition (by weight) of particle size ranges for sediment collected during winter in Munuscong Bay, St. Marys River, 1984.

Station	Particle Size Groups			
	< 10 u	< 60 u	10u-60 u	> 60 u
1	13.9	63.7	49.8	36.3
2	1.9	52.9	51.0	47.1
3	0.0	70.5	70.5	29.5
5	11.7	85.3	73.6	14.7
7A	12.6	68.7	56.1	31.3
Mean	8.0	68.2	60.2	31.8

BENTHIC MACROINVERTEBRATES

Taxonomic Composition

Forty-six taxa of benthic invertebrates were identified from Munuscong Bay samples during 1984. Approximately 40% of these taxa were ubiquitous throughout the bay, although only 6 and 4 taxa were present at all Ekman and PONAR sampling sites, respectively (Tables 7 and 8; Appendix B). Chironomidae larvae, the mayfly *Caenis* sp., the gastropod *Amnicola* sp., Oligochaeta, Nematoda, and Ostracoda were present at all Ekman sites and Chironomidae larvae, the mayfly *Hexagenia* sp., Oligochaeta, and Nematoda were found at all PONAR sites.

Chironomidae. Chironomidae larvae predominated in 7 of the 10 PONAR sample sites of Munuscong Bay, comprising from 34 to 65% of the organisms caught at those stations (Table 7). Peak chironomid abundance was 13.6-16.0 x 10^3 /m^2 at the northern stations of P2 and P2A. Other stations had chironomid densities between 1000 and 6000 /m^2 . This pattern was reversed for Ekman grabs where lowest chironomid abundance was recorded at station E2 and the highest Ekman grab density of 9.7 x $10^3/m^2$ was found at station E1 near the Munuscong River (Table 7).

Oligochaeta. Oligochaeta were among the top four most abundant organisms at all sites in Munuscong Bay. PONAR abundance ranged from 0.2 to 6.7 x $10^3/m^2$ at stations P1 and P7, respectively (Table 7). Some 1.1-13.6 x $10^3/m^2$ oligochaetes were present in Ekman samples with greatest abundance at station P6 (Table 8).

Ephemeroptera. Three genera of Ephemeroptera were collected from Munuscong Bay during 1984. *Hexagenia* was the most widespread genus, occurring at all PONAR sites and at all Ekman sites except station E6 (Tables 7 and 8). *Hexagenia* sp. was also the most abundant mayfly at all but 3 sampling sites. *Caenis* sp. was found in highest abundance at PONAR station P5 and Ekman station P8. *Ephemera* sp. was present at only half of the PONAR sites and at only one Ekman sampling site. Total ephemeropteran density ranged from 7 to 616/m^2 at stations P7 and P3, respectively.

Trichoptera. Trichoptera larvae were represented by 10 genera in Munuscong Bay. No genus was present at all sites, but *Polycentropus* sp. was the most abundant genus considering both PONAR and Ekman collections, comprising 39% of all larvae. *Phylocentropus* and *Mystacides* sp. comprised 21 and 15% of the trichopterans, respectively. Three genera were particularly rare in Munuscong Bay collections: *Oxyethira* sp. was collected only at station P8A by PONAR (Table 7); *Agrypinia* sp. and *Hydroptila* sp. were found only in Ekman grabs at station E8 (Table 8). Total average trichopteran densities ranged from 0.0 to 217/m^2 at PONAR sites and 0.0-129/m^2 at Ekman sites.

Gastropoda and Pelecypoda. Gastropods comprised only 1% of the total benthos collected from Munuscong Bay in 1984, but were a fairly diverse group. Nine genera were identified, and two species of *Valvata* sp. were found. *Amnicola* sp. was the dominant genus, comprising 31% of the Gastropoda encountered. Pelecypods were also rare with individuals comprising only about 0.5% of all benthos by number. Pelecypoda was dominated by *Sphaerium* sp. with

Table 7. Density estimates (numbers/m^2) for benthic macroinvertebrates collected with PONAR grabs from Munuscong Bay, St. Marys River, during May 1984.

	STATION									
	P 1	P 2	P 2A	P 3	P 4	P 5	P 7	P 7A	P 8	P 8A
Ephemeroptera										
Caenis sp.	7.0	70.0	77.0	0	7.0	224.0	0	0	84.6	0
Ephemera sp.	0	0	0	0	56.0	35.0	0	7.0	49.0	7.0
Hexagenia sp.	322.0	28.0	374.3	616.0	42.0	63.0	7.0	184.0	329.0	56.0
Trichoptera										
Ceractea sp.	0	7.0	0	0	7.0	14.0	0	0	0	7.0
Molanna sp.	0	0	0	0	0	0	7.0	0	0	21.0
Mystacides sp.	0	56.0	15.7	0	14.0	21.0	0	0	7.0	28.0
Oecetis sp.	35.0	7.0	0	0	0	14.0	0	0	0	0
Oxyethina sp.	0	0	0	0	0	0	0	0	0	7.0
Phylocentropus	105.0	0	8.7	0	0	0	0	0	0	0
Polycentropus sp.	0	133.0	7.0	70.0	35.0	14.0	0	0	0	14.0
Trianodes sp.	0	14.0	8.7	0	7.0	7.0	0	0	0	7.0
Diptera										
Ceratopogonidae	7.0	126.0	119.0	21.0	0	7.0	14.0	0	14.0	21.0
Chironomidae	4,417	13,685	15,974	6,615	3,598	6,384	1,519	2,534	2,646	4,452
Pupae	21.0	175.0	166.3	91.0	280.0	140.0	0	70.0	154.0	28.0
Collembola	0	0	0	0	70.0	70.0	0	0	0	0
Hemiptera										
Corixidae	7.0	0	0	0	0	7.0	0	7.0	7.0	0
Isopoda										
Asellus sp.	0	147.0	155.7	0	14.0	7.0	0	0	0	0
Lirceus sp.	0	371.0	28.0	0	119.0	7.0	0	0	0	105.0

Table 7. (Continued)

	STATION									
	P 1	P 2	P 2A	P 3	P 4	P 5	P 7	P 7A	P 8	P 8A
Amphipoda										
Gammarus sp.	0	0	0	0	35.0	28.0	0	0	0	0
Hyalella azeteca	0	1,470.0	101.3	98.0	875.0	1,568.0	0	0	133.0	1,197.0
Decapoda										
Orconectes sp.	0	0	0	0	14.0	0	0	0	0	0
Hydracarina	21.0	56.0	45.3	0	28.0	14.0	7.0	0	14.0	70.0
Gastropoda										
Amnicola sp.	0	49.0	0	14.0	133.0	77.0	14.0	0	0	56.0
Campeloma sp.	49.0	0	0	0	0	21.0	0	0	21.0	0
Elimia sp.	0	0	0	0	0	7.0	0	0	0	0
Gyraulus sp.	7.0	21.0	0	0	56.0	70.0	0	0	14.0	49.0
Helisoma sp.	0	0	8.7	0	0	0	0	0	0	0
Lymnaea sp.	7.0	0	0	0	0	21.0	0	0	0	0
Lymnacidae	0	0	0	7.0	0	0	21.0	0	0	21.0
Physa sp.	0	7.0	0	0	28.0	14.0	0	0	0	28.0
Valvata sincera	0	14.0	0	0	14.0	70.0	0	0	14.0	49.0
V. tricaranata	0	0	0	7.0	7.0	7.0	0	0	0	21.0
unknown	0	0	0	0	0	0	0	0	14.0	0
Pelecypoda										
Anodontoides	0	0	0	0	0	0	0	0	0	147.0
Pisidium sp.	0	14.0	0	0	28.0	14.0	42.0	63.0	0	91.0
Sphaerium sp.	112.0	0	0	0	35.0	35.0	0	7.0	7.0	42.0
Oligochaeta	6,734.0	1,890.0	728.0	805.0	1,344.0	1,834.0	210.0	3,836.0	3,584.0	889.0

BLANK PAGE

BLANK PAGE

BLANK PAGE

Table 7. (Continued)

	STATION									
	P 1	P 2	P 2A	P 3	P 4	P 5	P 7	P 7A	P 8	P 8A
Turbellaria	7.0	98.0	129.3	0	21.0	35.0	0	0	7.0	70.0
Nematoda	2170.0	2,555.0	2,985.0	1,897.0	2,401.0	1,988.0	917.0	1,547.0	1,190.0	3,857.0
Ostracoda	4,200.0	3,010.0	3,465.0	2,590.0	1,330.0	1,540.0	0	490.0	1,820.0	490.0
Hirudinea	14.0	0	0	7.0	0	0	7.0	0	0	0
Total	18,242	24,003	24,397	12,838	10,598	14,357	2,756	8,745	10,109	11,830

Table 8. Abundance estimates (numbers/m^2) for benthic macroinvertebrates collected with Eckman grabs from Munuscong Bay, St. Marys River, during May 1984.

	Station			
	E 1	E 2	E 6	E 8
Ephemeroptera				
Caenis sp.	21.5	7.2	107.5	344.0
Ephemera sp.	0	14.3	0	0
Hexagenia sp.	229.3	35.8	0	7.2
Trichoptera				
Agrypinia sp.	0	0	0	21.5
Hydroptila sp.	0	0	0	7.2
Mystacides sp.	7.2	0	0	0
Oecetis sp.	0	0	7.2	14.3
Phylocentropus sp.	78.8	0	0	0
Polycentropus sp.	0	0	7.2	86.0
Coleoptera				
Donacia sp.	0	0	0	7.2
Diptera				
Ceratopogonidae	28.7	7.2	0	28.7
Chironomidae	9,732.3	1,010.5	7,331.5	6,055.8
Pupae	43.0	0	215.0	444.3
Odonata				
Enallagma sp.	0	0	0	43.0
Hemiptera				
Corixidae	78.8	0	0	0
Lepidoptera				
Paraponyx sp.	0	0	0	14.3
Isopoda				
Asellus sp.	14.3	0	0	408.5
Lirceus sp.	0	14.3	0	996.2
Amphipoda				
Gammarus sp.	7.2	0	0	57.3
Hyalella azteca	35.8	71.7	0	229.3
Pontoporeia hoyi	0	0	0	14.3
Decapoda				
Orconectes sp.	0	0	0	7.2
Hydracarina	50.2	43.0	0	14.3

Table 8. (Continued)

	Station			
	E 1	E 2	E 6	E 8
Gastropoda				
Amnicola sp.	100.3	7.2	21.5	7.2
Campeloma sp.	28.7	0	14.3	0
Ferrisia sp.	0	0	0	7.2
Gyraulus sp.	50.2	0	0	107.5
Physa sp.	35.8	0	0	7.2
Valvata sincera	50.2	0	50.2	7.2
Valvata tricarinata	0	0	50.2	7.2
Pelecypoda				
Pisidium sp.	43.0	0	35.8	0
Sphaerium sp.	279.5	0	14.3	0
unknown	0	0	0	7.2
Oligochaeta	4,285.7	1,110.8	13,595.2	1,970.8
Turbellaria	129.0	7.2	0	28.7
Nematoda	5,876.7	716.7	2,931.2	2,150.0
Ostracoda	6,235.0	121.8	2,128.5	1,146.7
Hirudinea	14.3	0	0	28.7
Total	27,455.5	3,167.7	26,509.6	13,876.2

approximately equal densities collected at both the PONAR and Ekman sites (Table 7 and 8).

Amphipods. Amphipods were comprised of several taxa including *Gammarus* sp., *Hyalella azteca*, and *Pontoporeia hoyi*. Though this group comprised only 2.9 % of all benthos, amphipods were present at 7 of 10 PONAR sites and 3 of 4 Ekman sites. *Hyalella azteca* dominated the amphipods (98%) and a peak average density of 1,568/m^2 was found at PONAR station P5 (Tables 7 and 8).

Isopoda. Isopods were comprised of two genera: *Asellus* sp. (31.6%) and *Lirceus* sp. (68%). Isopoda was a rather minor group making up only 1.2% of all benthos, though a peak average density of 1,405/m^2 was observed at one Ekman site (E8; Table 8). Isopods were present at 3 of 4 Ekman sites and 5 of 10 PONAR sites.

Ostracoda. Almost 14% of all organisms from combined PONAR and Ekman samples were ostracods. This group was present at all Ekman sites (range in densities of 122-6,235/m^2) and at 9 of 10 PONAR sites (range in density of 490-4,200/m^2; Tables 7 and 8).

Littoral vs. Offshore Areas

Munuscong Bay benthos abundance ranged from 2,756-24,397/m^2 in PONAR samples and from 3,168-27,456/m^2 in Ekman dredges (Tables 7 and 8). These values are comparable to previous estimates of from 3,526 to 30,972/m^2 taken by PONAR in the eastern basin of Lake Munuscong (Liston et al. 1985). Benthos densities were generally higher in the shallow-water sites sampled by Ekman dredge. However, at station 2 (deep) PONAR dredge estimates were substantially greater than shallow-water values. Overall, benthos abundance was highest in PONAR samples of stations P2 and P1. Both stations were shallow and subject to river inputs. Ekman benthos abundance was greatest at stations E6 and E1, sites of greatest distance from the navigation channel. This pattern may be related to the increase in benthos toward the lee, or western side, of the river channels as seen in previous studies or as a general increase of habitat suitability towards shore (Liston et al. 1985).

Diversity (number of taxa) was nearly equal between the littoral and offshore stations at 41 vs. 37, respectively. Seven genera were found in the littoral zone that were not collected in offshore areas of Munuscong Bay including *Agrypinia* sp. and *Hydroptila* sp. (Trichoptera), *Donacia* sp. (Coleoptera larvae), *Enallagma* sp. (Odonata), *Paraponyx* sp. (Lepidoptera), *Pontoporeia* sp. (Amphipoda), and *Ferrisia* sp. (Gastropoda). Three of these taxa, *Donacia* sp., *Enallagma* sp. and *Paraponyx* sp., are strongly associated with vascular plants (Merritt and Cummins 1978) and thus would not be expected outside of the littoral zone. With one exception, all of the above taxa have only been found in the upper littoral zone in recent studies of the St. Marys River. The exception is the amphipod *Pontoporeia* sp. which in the past had been found in offshore areas as well as in the littoral zone (Liston et al. 1983).

Eight taxa were found in offshore sites that were not taken in samples from littoral areas of Munuscong Bay. These were the Trichoptera genera *Ceraclea* sp., *Molanna* sp., *Oxyethira* sp. and *Triaenodes* sp., Gastropoda of the genera

Elimia sp. and Helisoma sp., the Pelecypoda genus Anodontoides sp., and the order Collembola. The latter two taxa were not previously collected in recent sampling in the St. Marys River (Liston et al. 1985). Of the remaining above taxa all but Triaenodes sp. and Helisoma sp. had also been found only in offshore areas. None of these offshore taxa were very abundant and only two (Ceraclea sp. and Triaenodes sp.) occurred at more than two sites.

Regional Distribution and Abundance

Munuscong Bay stations showed high variability in the diversity and abundance of benthic organisms. Highest total densities of 24,003-24,397 /m^2 were found in the PONAR samples from station 2 near the navigation channel. However, the lowest total density of 2,756/m^2 was recorded at station 7 also near the channel. Benthos of off-channel sites were consistently of moderate density ranging from 10,108 to 18,242/m^2. Highest off-channel values were obtained at station 1, an area closest to the Little Munuscong and Munuscong Rivers (Figure 2). Highest diversity occurred along the southern shore of Munuscong Bay followed by open-water, navigation channel, and tributary stations. St. Marys River stations excelled in chironomids, trichopterans, and isopods, while tributary stations were high in oligochaetes and ostracods. Ephemeropterans and gastropods were found in greater diversity and abundance at the southern shore and open-water stations.

Ekman grab samples reveal a different pattern. Highest overall benthos abundance was at the tributary station (27,455/m^2) as compared to low densities in the Ekman sample of station 2 (3,167/m^2). Southern shore stations were of moderate benthic abundance and highest diversity . The Ekman channel station represented 13 taxa or nearly half of the tributary station. The southern shore exhibited the highest abundance of oligochaetes, trichopterans, gastropods, amphipods, and isopods. Chironomids were high in the Ekman dredges taken off the tributary rivers.

In general, diversity was highest along the southern shore, although highest benthic densities were obtained in the PONAR stations of the navigation channel and the Ekman station off the Munuscong River. It is unclear why benthic densities followed opposite patterns in the PONAR and Ekman samples. Without additional samples, it is difficult to establish reasons for such distributions.

Offshore benthos diversity and abundance appeared to be related to higher turbidities and winter sedimentation rates. Highest PONAR benthos densities were obtained at stations near the navigation channel and tributary inputs. Ekman benthos densities may be more variable due to variance in local conditions. A comparison of the physical/chemical characteristics of larval fish sampling sites demonstrates the higher variation among nearshore littoral areas than open-water offshore sites (Appendix A.3 and A.1). Moreover, vegetational densities were variable with higher stem densities observed at stations 6 and 8 along the southern shore. At these stations, the predominance of oligochaetes, trichopterans, gastropods, amphipods, and isopods may further reflect the higher vegetational densities which provide cover, increased areas of periphyton attachment, food, and habitat diversity (Allen 1975). Such a pattern was previously reported on the western side of the St. Marys River

(Liston et al. 1985) and may be related to increased habitat stability due to protection from wind and wave action (Hunt 1962). However, if wind-induced wave action was the major factor, we would expect to see reduced benthos densities at exposed sites like P5 and E6, which was not the case. Within Munuscong Bay, other factors such as vegetational cover and substrate characteristics may also be important.

Chironomids, however, predominate at sites off the Munuscong River and near the navigation channels where sedimentation was high, vegetation low, and substrates were fine and silty. The apparent reversal of high chironomid larval abundance in PONAR samples at station 2 (channel) and higher abundance in Ekman samples off the major tributaries, may relate to local conditions, particularly differences in substrate particle size. The PONAR site of station 1 was located quite some distance off the Munuscong River outflow, whereas PONAR samples at the channel were close to the river current. The somewhat larger particle size and other chemical characteristics of the near-channel and near-tributary zone may favor chironomid production.

Munuscong Bay vs. St. Marys River

When making comparisons between the 1984 data and that from previous years, several factors must be considered. Both a modified Gerking sampler and an Ekman grab were used to sample in the littoral zone of the St. Marys River during 1982-1983. Only the Ekman grab was used in the littoral zone during 1984 and thus a less diverse fauna would be expected. Open-water sampling in 1984, although relatively limited in scope, did use methods consistent with previous years.

Total open-water benthic invertebrate density (PONAR grabs) ranged from 2,765 to 24,397/m^2 in Munuscong Bay . The overall mean density of benthic invertebrates for open-water areas was 3,789/m^2 (Table 7). Densities in Munuscong Bay were generally less than upstream areas and greater than downstream regions of the St. Marys River as measured in 1982 and 1983 (Liston et al. 1985).

Total abundance of littoral zone benthic invertebrates ranged from 3,168 to 27,456/m^2 in Munuscong Bay during 1984 (Table 8). The overall mean density of invertebrates in the littoral zone (Ekman sites) of Munuscong Bay was 17,838/m^2. This average was greater than the mean densities at stations I, IV, and VII of the St. Marys River in 1982 and 1983. The mean densities in the littoral zones of the other stations sampled during 1982 and 1983 varied over the years, and no consistent trends were apparent (Liston et al. 1985).

Samples from Munuscong Bay in 1984 show a less diverse benthic invertebrate fauna as compared to other areas of the St. Marys River. Disregarding the multitude of Chironomidae genera (which were not enumerated in 1983 or 1984), 91 taxa and 74 taxa were identified in 1982 and 1983, respectively. In contrast, only 45 taxa were identified in samples from Munuscong Bay in the spring of 1984. On the average, 42 taxa were present at each station in the spring of 1982, 36 in the spring of 1983, and only 19 in 1984. The number of taxa present ranged from 9 to 28 in Munuscong Bay in 1984. The range was from 32 to 52 in

1982 and from 26 to 43 in 1983. These differences may be the result of the larger sample size and the diversity of gears used in 1982 and 1983.

The Lepidoptera genus Paraponyx sp. was represented in 1984 samples from Munuscong Bay. While this genus was observed elsewhere in the St. Marys River in 1982 and 1983, it had not been taken in the spring. The genus Anodontoides sp. of the order Pelecypoda was identified in a 1984 sample from Lake Munuscong. It had not been observed in any previous sampling efforts (Liston et al. 1985).

FISH LARVAE

A total of 245 ichthyoplankton samples were taken on 9 dates from 23 April through 20 August 1984 (Appendix C). A total of 6,731 larvae of 33 taxa and representing 12 families were collected (Table 9). Definite trends in temporal distribution and species succession of larval fish were observed and have been previously reported in the St. Marys River (Liston et al. 1985) and other bodies of water (Amundrud et al. 1974, Jude et al. 1980). Densities of ichthyoplankton were low in spring samples and were dominated by lake herring, lake whitefish, and burbot larvae. In late spring-early summer larval fish densities increased markedly and were primarily comprised of rainbow smelt and yellow perch. Greatest densities were observed in summer samples which were dominated by Cyprinidae (primarily spottail shiner and emerald shiner), Percidae (logperch and johnny darter), and Centrarchidae (Lepomis spp. and black crappie).

Ichthyoplankton were unevenly distributed in Munuscong Bay. Stations 1, 5, and 8 had the greatest concentration of larvae with average densities of 183.1, 141.8 and 129.7/100m^3, respectively. Station 1 is located off the mouth of the Munuscong River in the southwest corner of Munuscong Bay and stations 5 and 8 are along the southern shore. Average 1984 densities of larval fish were generally less than 100/100 m^3 at all other stations.

The greatest number of larvae were generally taken with the half-meter push net. However, calculated densities were highest for the pull net samples from the macrophyte beds. A peak pull-net density of 782.4/100m^3 was nearly an order of magnitude greater than ichthyoplankton densities at macrophyte edge (push) and offshore stations (meter tows). Liston et al. (1985) reported similar distributions of larval fish along the entire course of the St. Marys River. As in other parts of the St. Marys River, macrophyte beds appear to be the prime nursery and spawning areas for fishes.

Approximately 12 taxa were considered common (>100 individuals collected) in Munuscong Bay, but only three species were clearly abundant (>1000 individuals) and these comprised over 60% of the total number (Table 9). Rainbow smelt, emerald shiner, and yellow perch were the most abundant larvae in Munuscong Bay. Their abundance was also reflected in their abundance as adults and they were dominant larvae in the previous studies conducted throughout the St. Marys River. However, unidentified Cyprinidae tended to be more abundant and yellow perch were less common than in St. Marys River past collections (Liston et al. 1985).

Table 9. Total number and percentage composition of fish larvae collected from Munuscong Bay in 1984.

Species	Total Number	Percent Total Number
Rainbow smelt	1,893	28.1
Emerald shiner	1,140	16.9
Yellow perch	1,019	15.1
Cyprinidae	597	8.7
Spottail shiner	551	8.2
Black crappie	236	3.5
Logperch	199	3.0
Common carp	183	2.7
Lepomis spp.	179	2.6
Gizzard shad	127	1.9
Johnny darter	108	1.6
Lake herring	101	1.5
Burbot	76	1.1
Percidae	60	0.9
Golden shiner	49	0.7
Trout-perch	37	0.6
Lake whitefish	32	0.5
Walleye	23	0.3
Alewife	16	0.2
Mimic shiner	16	0.2
Rock bass	8	0.1
Pink salmon	6	0.1
White sucker	4	<0.1
Catostomidae	3	<0.1
Pimephales spp.	3	<0.1
Bloater	2	<0.1
Cottus spp.	2	<0.1
Deepwater sculpin	2	<0.1
Moxostoma spp.	1	<0.1
Freshwater drum	1	<0.1
Brook stickleback	1	<0.1
Ninespine stickleback	1	<0.1
Unidentifiable	55	0.8
Total	6,731	

Major Taxa

Cyprinidae. The minnows, as a group, were the most abundant larvae collected in the Munuscong Bay, representing 34% of the larval catch. This reflects their overall abundance as adults in the St. Marys River and their importance as a major component of the river and lake ecosystems. Emerald shiner and spottail shiner were the most abundant cyprinids collected at 16.9 and 8.2% of the catch. However, occasional high densities of common carp (907/100m^3) and golden shiner (826/100m^3) were also encountered. No larval cyprinids were collected before June and only spottail shiners became abundant in June. All other cyprinid larvae did not become abundant until July and August.

Spottail shiner larvae were first collected in early June in high densities (286-842 larvae/100m^3) at station 1, located off the mouth of the Munuscong River (Table 10). Larvae became more widely distributed in early July and several densities greater than 100/100 m^3 were recorded. Some spottail shiner larvae were collected through early August, although at greatly decreased abundance. At the time of first larval appearance, water temperatures ranged from 11-18 °C with highest temperatures in areas of greatest larval density (Appendix A). Spottail shiner larvae were concentrated at station 1 off the north of the Munuscong River, station 2 in littoral waters, and stations 5 and 8 near shallow bays along the southern edge of Munscong Bay. Densities were similar to those reported in other areas of the St. Marys River (Liston et al. 1985). At most stations, spottail shiner larvae achieved greatest density in the near-shore littoral zone. This pattern of abundance was previously documented by Liston et al. (1985) in the St. Marys River and by Jude et al. (1980) and Liston et al. (1980) in other bodies of water.

Emerald shiner larvae were first collected in early July in low numbers (1-32/100 m^3) when water temperatures were 14.5-17.5 °C (Appendix A). However, peak densities of 236 larvae/100 m^3 were not attained until early August and some larvae were taken throughout the rest of the summer (Table 11). Water temperatures during peak larval abundance ranged between 18-22 °C (Appendix A). Unlike other cyprinid larvae, emerald shiner were most abundant at stations 4, 5, and 7, in the more open offshore areas of the lake. However, densities of emerald shiner in Munuscong Bay were not as high as Liston et al. (1985) recorded in other areas of the St. Marys River (up to 1,095 larvae/100 m^3) suggesting Munuscong Bay may not be as suitable a spawning habitat for this species.

Common carp were the third most abundant cyprinid larvae identified in Munuscong Bay, and comprised 2.7% of the total number of larvae collected. This is nearly 4 times greater than observed in other areas of the St. Marys River (Liston et al. 1985). Common carp were first collected in early July when water temperatures ranged between 14 and 20 °C (Appendix A). Greatest densities (43-1,211 larvae/100 m^3) were recorded in shallow littoral areas (Table 12) where water temperatures were highest. Larvae were collected throughout the remainder of the summer, although only one individual was taken on 21 August. The peak mean abundance of larval carp (104/100 m^3) was greater in Munuscong Bay than Liston et al. (1985) observed in other areas of the St. Marys River.

Table 10. Mean densities (no./100 m^3) of spottail shiner larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	842	286	0	3	<1	0	0	3	5	6	0	0	0	1
6-19	0	0	32	0	0	0	0	0	96	3	9	0	0	11
7-3	582	0	108	1	0	0	0	1	57	8	2	<1	162	12
7-23	22	0	0	0	0	0	0	0	0	0	0	0	0	1
8-6	0	2	38	0	<1	0	0	0	1	0	0	0	0	3
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 11. Mean densities (no./100 m^3) of emerald shiner larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-3	0	0	0	0	0	0	0	0	0	1	0	7	32	0
7-23	0	2	0	1	2	1	7	0	123	13	112	1	0	4
8-6	0	11	38	2	2	11	1	182	236	75	84	9	0	38
8-21	0	4	0	0	0	0	0	1	63	23	5	1	0	76

Table 12. Mean densities (no./100 m^3) of carp larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-3	143	3	1211	0	0	1	0	12	55	20	1	0	0	6
7-23	0	0	0	0	0	0	0	3	9	3	0	1	0	0
8-6	0	0	0	0	0	0	0	4	4	2	1	<1	0	3
8-21	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Larval golden shiners were not common in most of the St. Marys River (Liston et al. 1985), but were found in abundance in limited areas of Munuscong Bay. Larvae were collected from mid-June throughout the summer when water temperatures were 17.5-23 °C (Appendix A). Golden shiner larvae were in highest abundance in the shallow littoral zone of station 8, where densities often exceeded 100/100 m^3 and ranged up to 826 larvae/100 m^3. The shallow littoral stations of 1 and 2 were the only other regions where golden shiner were collected.

Many cyprinid larvae could not be identified. Most of these specimens were thought to be mimic shiner larvae. Indeed, adult mimic shiners were the most abundant minnow collected with trawls in Munuscong Bay in 1984. Unidentified cyprinid larvae were collected on all dates from June through August. However, they did not become abundant until early July, and reached peak abundance (392/100 m^3) and widest distribution in early August (Table 13). Most unknown minnow larvae were collected in the shallow littoral zones where densities greater than 100 larvae/100 m^3 were common. Some densities of more than 100/100 m^3 were recorded in offshore shallow areas, but in general, densities at these areas were considerably less.

Rainbow smelt. Rainbow smelt was the most abundant larval species in Munuscong Bay in 1984, comprising over 28% of the larval catch (Table 9). Rainbow smelt were also the dominant larvae in the St. Marys River system in previous years (Liston et al. 1982, 1983, 1985). Larvae were first collected in early May at low densities (<10/100 m^3) at stations 1, 5, and 8, along the westward and southern shore of Munuscong Bay (Table 14). Water temperatures ranged from 7-10.5 °C at that time. Rainbow smelt larvae remained low in abundance until early June when water temperatures reached 10-14 °C and maximal densities of over 100 larvae/100 m^3 were relatively uniform at stations 2-5 and 7 with values ranging from 100 to 250/100 m^3. Liston et al. (1985) reported peak spawning times of rainbow smelt were early to mid-June along the St. Marys River, being somewhat later along the more northern (upriver) areas. In this study, fewest rainbow smelt were collected at stations 1, 6, and 8 which were closest to the southern shoreline.

Larval rainbow smelt densities dropped markedly after the June maximum although some were collected on each date through late August. Most larvae were recently hatched with a yolk sac present and an average length of 6-7 mm. Larval rainbow smelt were somewhat larger at station 1 near Munuscong Bay tributaries (mean= 11.8 mm). Few larvae were collected in the vegetated, littoral zone and densities were comparable between the littoral edge and offshore areas. These data suggest that some rainbow smelt spawning may occur early in the Munuscong River as water temperatures warm rapidly when compared to Munuscong Bay (Appendix A; Table 14). However, most spawning may take place in central Munuscong Bay or larvae may be transported there from the downbound channel on the west side.

Yellow Perch. Yellow perch was the third most abundant larval fish representing over 15% of the total catch (Table 9). Yellow perch is a spring spawner with larvae present during the same period as rainbow smelt. Yellow perch larvae were first collected in early May at stations 1 and 8 to the west and south in Munuscong Bay (Table 15). Densities peaked rapidly in late May

Table 13. Mean densities (no./100 m^3) of Cyprinidae larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	3	0	0	0	0	0	0	0	0	0	0	0	0
6-19	0	0	0	0	0	0	0	0	1	0	0	0	0	0
7-3	39	0	36	0	0	0	0	2	4	0	0	0	292	0
7-23	0	0	14	1	1	0	0	2	51	1	8	0	0	16
8-6	0	111	0	2	<1	1	<1	19	143	31	46	0	392	69
8-21	0	2	337	0	0	0	<1	0	7	2	1	0	0	7

Table 14. Mean densities (no./100 m^3) of rainbow smelt larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	5	0	0	0	0	0	0	5	0	0	0	0	7
5-22	0	16	72	1	0	6	1	0	6	26	6	<1	0	8
6-4	0	8	0	94	114	154	122	118	185	38	248	136	0	82
6-19	0	0	0	14	6	8	13	10	21	6	7	2	0	34
7-3	0	0	0	1	8	1	4	6	6	9	6	8	0	9
7-23	0	0	0	0	5	3	7	6	1	22	5	2	0	8
8-6	0	0	0	2	<1	9	<1	0	3	1	0	6	0	0
8-21	0	0	84	10	1	11	1	2	0	1	0	0	0	0

Table 15. Mean densities (no./100 m^3) of yellow perch larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	7	0	0	0	0	0	0	0	0	0	0	478	4
5-22	1,465	501	0	1	1	0	<1	7	14	36	17	0	2,000	174
6-4	281	85	5	10	<1	2	1	1	3	2	1	0	352	70
6-19	83	6	97	1	<1	1	1	1	2	23	0	0	0	36
7-3	78	3	0	1	<1	2	<1	0	2	0	0	<1	97	0
7-23	0	1	0	0	0	0	0	0	0	0	0	0	0	1
8-6	0	0	0	0	0	0	0	0	1	0	0	0	65	0
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

when as many as 1,465-2,000 larvae/100 m^3 were observed in littoral areas at these stations. Water temperatures were 16-16.5 °C in the littoral zone of station 1 (Appendix A.3) and 13-16 °C along the littoral edge of station 8 (Appendix A.2). This corresponds to the timing of peak densities of yellow perch as recorded in other areas of the St. Marys River in past years (Liston et al. 1985). Yellow perch larvae remained abundant in Munuscong Bay through early June after which few larvae were captured.

Spatially, yellow perch were concentrated in station 1 near the mouth of the Munuscong River, and at station 8 in the small bay of the southern shore. Yellow perch larvae were scarce at other stations (almost always <50/100 m^3), while at stations 1 and 8, densities greater than 100/100 m^3 were common and at times exceeded 1,000 larvae/100 m^3. Greatest densities occurred in the shallow littoral areas (pull nets) and very few yellow perch larvae were observed in channel samples (Table 15). Liston et al. (1985) also reported excellent yellow perch spawning and nursery areas in the shallow littoral zone of the bays along the southern shore of Lake Munuscong.

Yellow perch larvae in early May were newly hatched and ranged from 5.4-7.1 mm in total length. Growth was consistent and larvae averaged 8.0 mm, 10.8 mm, 18.4 mm, and 25.8 mm by late May, early June, late June, and early July, respectively. This is an average of 0.47 mm/day, which is similar to that reported for 1982 yellow perch larvae in the St. Marys River (Liston et al. 1985). A second cohort in late June was identified based on length measurements which indicated a few larvae (n=8) were newly hatched (mean length 6.7 mm) and could be followed into July (n=8, mean length 7.6 mm). In previous studies a late cohort was also reported in the upper St. Marys River and the Izaak Walton Bay area (above the Soo Locks) (Liston et al. 1985). Indeed, many of the small larvae collected in late June and early July of 1984 were in channel samples or in littoral regions of station 2 and 3 bordering on the northern edge of Munuscong Bay adjacent to the down-bound shipping channel. The slower warming temperatures of the offshore and channel regions may account for this pattern.

Black crappie. In previous studies of the St. Marys River, black crappie larvae and adults were rarely collected, although relatively large numbers of juveniles were taken, especially in 1983. It was hypothesized that Munuscong Bay may be the source of these centrarchids (Liston et al. 1985), and indeed, 1984 studies in Munuscong Bay have corroborated this hypothesis.

Black crappie were the sixth most abundant larvae taken in Munuscong Bay comprising 3.5 % of the catch (Table 9). However, black crappie were highly restricted in their distribution. Larvae were first collected in early June in the shallow littoral areas of station 1 where water temperatures were 18.0 °C (Appendix A.3). A peak abundance of 5,747 larvae/100 m^3 was observed in late June, although some larvae were collected through early August (Table 16). All larvae, except for one individual were taken at station 1 and most of these were collected in the shallow littoral areas off the mouth of the Munuscong River. Black crappie larvae grew fast, averaging 5.0 mm in early June and 37 mm by early August.

Lepomis spp. Pumpkinseed sunfish (L. gibbosus) and bluegill larvae (L. macrochirus) were difficult to separate. However, no adult bluegill were

Table 16. Mean densities (no./100 m^3) of black crappie larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	393	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	5,747	88	0	0	0	0	0	0	1	0	0	0	0	0
7-3	388	0	0	0	0	0	0	0	0	0	0	0	0	0
7-23	0	5	0	0	0	0	0	0	0	0	0	0	0	0
8-6	80	0	0	0	0	0	0	0	0	0	0	0	0	0
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

captured in 1984 suggesting most *Lepomis* spp. were pumpkinseed sunfish. *Lepomis* spp. larvae were first collected in mid-June in Munuscong Bay at water temperatures of 18-20 °C (Appendix A). Peak densities (4,537 larvae/100 m^3) were observed in early July and some larvae were collected throughout the summer (Table 17).

Larval *Lepomis* spp. were highly segregated spatially. Two distinct areas served as nursery sites: the west and northwest end of Munuscong Bay (stations 1 and 2) and the shallow basin along the southeastern edge (station 8). *Lepomis* spp. larvae were all collected (except one) in the shallow littoral areas of these stations, suggesting the importance of shallow macrophyte stands to this group of fishes. Liston et al. (1985) had previously noted the attraction of larval *Lepomis* spp. to shallow, weedy areas in the St. Marys River and found densities similar to those in Munuscong Bay. Moreover, this concentration in densely weedy areas supports the assertion that these larvae were pumpkinseed sunfish rather than bluegills which prefer more open, less vegetated, habitats.

Lepomis spp. larvae did not seem to grow as fast as black crappie larvae and only averaged 29.8 mm in total length by late August. This suggests a mean growth rate of 0.40 mm/day. However, growth rates were apparently much slower earlier in the summer and averaged only 0.2 mm/day from late July through early August.

Lake herring and lake whitefish. Lake herring and lake whitefish larvae were present as spring cohorts and were some of the earliest larvae of Munuscong Bay. Lake herring and lake whitefish represented 1.5 and 0.5% of the total larval catch (Table 9). Both species had similar temporal and spatial distributions.

Lake herring were most widely distributed during initial ichthyoplankton collections on 23 April when water temperatures were 3.5-7.0 °C (Appendix A). At this time, some larvae were collected throughout the Munuscong Bay sampling regions (Table 18). This suggests greatest hatching and dispersal may have occurred prior to 23 April. Most larvae were without yolk and averaged 10.3-11.4 mm total length. However, peak densities of lake herring were not recorded until early May at up to 50 larvae/ 100 m^3. Some larger, more advanced larvae (13.3-32.8 mm) continued to be collected through 19 June.

Larval lake herring were unevenly distributed in Munuscong Bay. Most larvae were concentrated at the western and northwestern corner of the bay (stations 1 and 2; Table 18). However, a temporal interaction also occurred where larvae were initially more abundant at station 2 and more abundant at station 1 later in May. This suggests either that earlier hatching occurred around station 2 (Kemps Point), or that larvae were drifting into this area from the downbound channel along the western side of Neebish island (rock cut). Larvae then moved into warmer water off the mouth of the Munuscong River (station 1) presumably to feed. This is partially corroborated by length data which shows substantially larger larvae (13.3-32.8 mm) were present at station 1 in late May-early June than recorded at station 2 (range 10.6-13.9 mm) in late April-May. However, length data also suggests some recently hatched larvae were also taken at station 1 in late April through early May.

Table 17. Mean densities (no./100 m^3) of *Lepomis* spp. larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	124	0	518	0	0	0	0	0	0	0	0	0	0	0
7-3	272	1	36	0	0	0	<1	0	0	0	0	0	0	4,537
7-23	0	0	0	0	0	0	0	0	0	0	0	0	0	159
8-6	0	0	0	0	0	0	0	0	0	0	0	0	0	131
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	62

Table 18. Mean densities (no./100 m^3) of lake herring larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION														
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	12	15	3	1	3	2	0	6	0	2	0	0	1
5-8	0	9	0	50	0	1	0	1	0	0	0	0	0	1
5-22	31	8	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	8	0	3	0	0	0	0	0	0	0	0	0	0
6-19	0	1	0	0	0	0	0	0	0	0	0	0	0	0
7-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Larvae of the other coregonid, lake whitefish, were first collected in late April at densities up to 31/100 m^3 (Table 19). They reached peak abundance in early May when as many as 130 larvae/100 m^3 were recorded at one station. Although lake whitefish were abundant on 22 May, no larvae were collected two weeks later on 4 June.

Lake whitefish exhibited some distinct distributional differences when compared to lake herring. For example, lake whitefish were consistently common at station 2, off Kemps Point. And likewise, the single greatest density (130/100 m^3) was observed at station 8 along the southern edge of Munuscong Bay. However, this distribution could have been an artifact of sampling effort since pull nets were included only at stations 1, 2, and 8. Larval lake whitefish were more restricted to the shallow littoral area than were the more pelagic lake herring larvae which were collected in greater numbers in the push nets taken off the macrophyte edge.

Liston et al. (1985) reported markedly higher concentrations of lake herring and lake whitefish larvae in other areas of the St. Marys River. In these previous studies, Raber Bay and Izaak Walton Bay were especially important areas for lake whitefish. Coregonids were abundant mainly in the northern region of the eastern basin of Lake Munuscong which was not sampled in 1984. Also, in all years of study, some of the highest densities of larval lake herring were recorded in the St. Marys River upstream and downstream from the Munuscong Bay study sites. The early spawning behavior in late fall and the early hatching of coregonids in April (Auer 1982) suggest coregonids deserve special attention regarding the effects of extended navigation. Apparently, coregonids, and lake herring in particular, require spawning and nursery areas adjacent, but sheltered from, the river channels.

Walleye. Adult walleye were the most abundant fish in trap net collections in Munuscong Bay. They are an important part of the fisheries community throughout the lower St. Marys River (Liston et al. 1985). However, little data is available on walleye larvae in the St. Marys River. Based on sporadic collections of walleye larvae nearby, Liston et al. (1985) hypothesized that Munuscong Bay may be an important walleye spawning area. In 1982, large advanced larvae were collected at peak densities of 32/110 m^3 in the eastern portion of Lake Munuscong. Liston et al. (1985) were also perplexed by the abundance of spawning adult walleye but lack of larvae in 1982. They recommended further sampling in the shallow water areas of Munuscong Bay.

In 1984, almost all Munuscong Bay larval walleye were taken on a single date in late May at water temperatures of 12-16 °C. Densities ranged from 1-18 larvae/100 m^3 (Table 20). Most larvae were collected by push nets in the shallow offshore areas of the southern edge of Munuscong Bay and at station 1 to the west. Greatest densities (18 larvae/100 m^3) were off the mouth of the Munuscong River (station 1) suggesting this tributary may be an important walleye spawning ground.

Most larvae were young and still retained some yolk material. Larvae averaged 8.0-10.1 mm in total length. Evidently walleye larvae grow rapidly and are quickly able to avoid ichthyoplankton gear. Further studies should include a more concentrated effort (e.g. collections every third day for a short

Table 19 . Mean densities (no./100 m^3) of lake whitefish larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	1	31	3	0	0	0	0	2	0	1	0	12	0
5-8	0	0	20	9	0	0	<1	0	0	0	0	0	130	2
5-22	31	1	24	3	2	1	0	0	1	0	0	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 20 . Mean densities (no./100 m^3) of walleye larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	18	7	0	0	0	0	0	2	1	6	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	2	0	0	0
6-19	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7-3	0	0	0	0	0	0	1	0	0	0	0	0	0	0
7-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8-21	0	0	0	0	0	0	0	0	0	0	0	0	0	0

period of time from mid-May to early June) and should be limited to those areas observed to be walleye spawning grounds (Munuscong River and the southern shore of Munuscong Bay).

Pink Salmon. Pink salmon runs are observed every year in the St. Marys River but odd year spawning runs are considerably larger (Emery 1981). Indeed, Liston et al. (1985) collected greatest numbers of adult pink salmon in 1983. In the spring of 1984, six larvae were collected in Munuscong Bay. However, in the prior odd year spawning (1981) and subsequent spring (1982) hatching, Liston et al. (1985) only collected one pink salmon larva in the entire St. Marys River.

Pink Salmon larvae were collected from ice-out (late April) until late May. Densities were always low (1-2/100 m^3) and fish were collected only at stations 2, 5, and 7, suggesting they were transported down the rock-cut channel (west side of Neebish Island). It is quite probable that pink salmon spawn around the rock-cut and Moon island areas since they require less silty, rocky substrates as are available at thes sites. No larvae and few adult spawners were found at station 1 discouraging any hypothesis of major tributary runs up the Munuscong and Little Munuscong Rivers.

Burbot. Burbot were a less common component of the St. Marys River fish community. However, they do provide a small winter fishery of incidental catch, particularly on Munuscong Bay. Burbot larvae were first collected in late April and maximum numbers were taken in early May (up to 12/100 m^3). Some larvae were collected until mid-June. These densities are considerably lower than peaks reported in other areas of the St. Marys River (Liston et al. 1985). Burbot larvae were most frequently collected at northeastern stations (2, 3, and 7) which are bordered by the down-bound navigation channel. Nearly all larvae were newly hatched (3.5-4.5 mm) and contained large amounts of yolk. These data suggest Munuscong Bay is most likely not a suitable habitat for burbot spawning and larvae are either tranported via the downbound channel and/or river spawning occurs along the deeper northeastern edge.

Gizzard shad. Liston et al. (1985) were surprised by the paucity of gizzard shad larvae and the abundance of juveniles in other portions of the St. Marys River. They speculated that gizzard shad may primarily spawn in tributary rivers and the mouth of the lower St. Marys River. Indeed, studies in Munuscong Bay suggest the tributary rivers may be of some importance. Larval gizzard shad were collected in July and August up to densities of 90/100 m^3. Most larvae were taken at station 6 near the mouth of the Gogomain River. Larvae were not newly hatched (all lacked yolk) and varied widely in length from 6.4-16.3 mm in late July, 6.9-24.3 mm in early August, and 20-22.9 mm in late August. Perhaps, gizzard shad spawn in tributary rivers and the larvae may then be transported or migrate down to Munuscong Bay as they grow.

Other percids: Besides yellow perch, two other species of percid larvae, johnny darter and logperch, were abundant in Munuscong Bay. These species provide some forage to piscivores in the system. The larvae of these species were present throughout the summer and were ubiquitous throughout Munuscong Bay.

Johnny darter larvae were collected mainly from mid-June to early August, with peak abundance (39 larvae/100 m^3) in July (Table 21). Greatest density of larvae were observed in shallow, littoral areas, although johnny darter larvae were collected more frequently at shallow offshore push net sites.

Logperch larvae were present for a much longer time suggesting an extended spawning period. They were first collected in low numbers in late May-early June, but peak densities (>100/100 m^3) were not observed until August (Table 22). Temporal differences may have been the result of differential warming rates in Munuscong Bay, as most larvae collected early were taken at station 1 off the mouth of the Munuscong River. Later in the summer, larvae were taken throughout the Bay, although densities at station 2 were markedly greater than at any other station. In previous studies, adult logperch were common at offchannel sites just upstream of this station (Liston et al. 1985) suggesting transport of larvae into Munuscong Bay may be of significance.

JUVENILE AND ADULT FISH

Bottom Trawls

A total of 32 trawl samples were taken (four at each of the eight stations; Figure 7) during May through August, 1984. This resulted in the collection of 6,178 fish of 27 species and 12 families (Table 23). As in other areas of the St. Marys River, Cyprinidae and Percidae were most widely represented with five species each. Other families were represented by only one or two species. Trout-perch were most abundant, followed by yellow perch, mimic shiner, and spottail shiner. Together, these four species comprised nearly 85% of the numerical catch (Table 23). Besides yellow perch, game species were relatively minor components of the trawl catch. White sucker, walleye, yellow perch and trout-perch were by far the most important fish in terms of biomass representing over 67% of the catch by weight.

The four most abundant species (trout-perch, yellow perch, mimic shiner, and spottail shiner) strongly dominated the demersal community at each station, collectively comprising between 72% and 89% of the total numerical catch. Trout-perch, yellow perch, spottail shiner, johnny darter and logperch were captured at all stations, although relative abundance varied between dates and stations (Table 24). The number of species present at each station ranged from a low of 10 at station 7A (deep) to a high of 18 at station 2A (deep). Many of these species were incidental, comprising less than 1% of the total number taken at a given station. The number of common, non-incidental, species ranged from 5 collected at station 8, to 10 at stations 2 and 3.

The demersal fish community of Munuscong Bay was similar to that of previous sampling in the lower St. Marys River (Liston et al. 1985). In general, earlier trawl samples collected in the eastern basin of the Lake Munuscong resembled those of the present study. The St. Marys River downstream of Neebish Island contains relatively large areas of shallow water and tends to be more turbid than upstream sites. These characteristics affect the plant community composition which in turn affects the entire biological system.

Table 21. Mean densities (no./100 m^3) of johnny darter larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6-19	0	0	0	0	0	0	0	0	6	14	0	0	0	21
7-3	319	0	0	1	1	0	<1	0	6	0	1	0	32	1
7-23	0	0	28	3	1	22	5	5	6	6	1	0	0	3
8-6	0	0	0	0	<1	0	<1	2	3	1	0	0	0	1
8-21	0	0	0	0	0	0	0	0	0	0	<1	0	0	0

BLANK PAGE

BLANK PAGE

BLANK PAGE

Table 22. Mean densities (no./100 m^3) of logperch larvae collected in Munuscong Bay, St. Marys River, 1984.

	STATION													
	1		2			3		4	5	6	7		8	
Date	L1	S1	L2	S2	C2	S3	C3	S4	S5	S6	S7	C7	L8	S8
4-23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5-22	31	4	0	0	0	0	0	0	1	0	0	0	0	3
6-4	0	4	0	0	0	0	0	0	1	0	0	0	0	1
6-19	83	1	0	0	0	0	0	0	0	0	0	0	0	0
7-3	0	3	18	6	6	3	1	5	3	0	6	5	0	6
7-23	0	1	14	38	2	2	1	7	1	11	5	0	0	14
8-6	0	3	114	2	<1	4	2	2	3	2	7	0	0	13
8-21	0	0	169	2	0	0	<1	0	1	0	0	0	0	1

Table 23. Total number, total weight (grams), and percentage composition of fish captured by trawl in Munuscong Bay during 1984.

Species	Total Number	% TN	Total Weight	% TW
Trout-perch	1,741	28.2	7,486	12.0
Yellow perch	1,185	19.2	9,661	15.4
Mimic shiner	1,146	18.5	1,714	2.7
Spottail shiner	1,139	18.4	2,811	4.5
Johnny darter	339	5.5	279	0.4
Logperch	112	1.8	422	0.7
White sucker	69	1.1	14,210	22.7
Bluntnose minnow	69	1.1	113	0.2
Mottled sculpin	69	1.1	102	0.2
Rock bass	48	0.8	3,874	6.2
Ninespine stickleback	46	0.7	273	0.4
Sand shiner	40	0.6	58	0.1
Black crappie	37	<0.6	42	0.1
Emerald shiner	33	0.5	115	0.2
Rainbow smelt	32	0.5	145	0.2
Walleye	29	0.5	10,094	16.1
Northern pike	13	0.2	3,441	5.5
Iowa darter	12	0.2	10	<0.1
Pumpkinseed	4	<0.1	39	0.1
Lake herring	3	<0.1	151	0.2
Brook stickleback	3	<0.1	3	<0.1
Silver redhorse	2	<0.1	2,932	4.7
Burbot	2	<0.1	3,109	3.4
Brown bullhead	2	<0.1	1,164	1.9
Muskellunge	1	<0.1	1,050	1.7
Lake whitefish	1	<0.1	240	0.4
Smallmouth bass	1	<0.1	37	0.1
Total	6,178		62,575	

Table 24. Catch-per-effort of fish at various trawl stations in Munuscong Bay during 1984.

	STATIONS							
species	1	2 (shallow)	2A (deep)	3	4	7 (shallow)	7A (deep)	8
Trout-perch	64.2	32.8	8.8	29.2	65.7	27.0	92.2	115.2
Yellow perch	12.2	35.8	60.2	53.2	75.0	1.0	43.0	15.2
Mimic shiner	1.0	43.0	190.8	19.2	27.0	0	4.5	1.0
Spottail shiner	6.2	28.2	36.5	21.5	43.0	1.0	126.2	22.0
Johnny darter	2.8	3.8	9.0	8.0	18.2	2.8	26.2	14.0
Logperch	1.5	16.2	1.8	4.2	1.2	0.2	2.5	0.2
White sucker	0.2	4.8	3.2	2.5	0.8	0	5.5	0.2
Bluntnose minnow	0	15.2	2.0	0	0	0	0	0
Mottled sculpin	0	1.2	9.8	2.0	1.5	0.2	2.2	0.2
Rock bass	0.8	4.5	2.5	1.5	0.8	0	2.0	0
Ninespine stickleback	0	3.2	1.0	0.2	1.0	0.5	5.5	0
Sand shiner	0	0.2	2.0	0.1	2.8	0	0	4.8
Black crappie	9.0	0	0	0.2	0	0	0	0
Emerald shiner	2.5	1.2	0.2	0	0.8	0	27.8	0.8
Rainbow smelt	0.2	1.8	1.8	1.5	0.8	1.8	0.2	0
Walleye	4.8	0	0.8	0	0.2	0.2	0.5	0.8
Northern pike	1.2	0.2	0.8	0	0.5	0	0.2	0.2
Iowa darter	0	1.2	0.8	0	1.0	0	0	0
Pumpkinseed	0.2	0	0	0.5	0.2	0	0	0
Lake herring	0	0	0	0	0.2	0.5	0	0
Brook stickleback	0	0	0.8	0	0	0	0	0
Silver redhorse	0.5	0	0	0	0	0	0	0
Burbot	0	0	0	0	0.5	0	0	0
Brown bullhead	0.2	0	0	0	0	0	0	0.2
Muskellunge	0	0	0	0	0	0	0	0.2
Lake whitefish	0	0	0	0	0.2	0	0	0
Smallmouth bass	0	0.2	0	0	0	0	0	0
All species	107.8	193.8	332.5	143.2	241.5	35.2	338.5	175.2

Trout-perch. Trout perch were quite abundant and widely distributed in Munuscong Bay, occurring in all trawl samples (Table 24). However, this species was not evenly distributed. Abundance was greatest at trawl stations 7 (shallow) and 8. Catches at stations 1 and 4 were approximately equal, as were catches at stations 2 (shallow), 3, and 7 (deep). Catch at station 2 (deep) was considerably lower than that of all other stations. Overall catch peaked in early summer, declining thereafter.

At each station, male and female trout-perch in spawning condition were captured between May through June. Relatively few YOY trout perch were collected as compared to the other areas of the St. Marys River in previous years. This was probably due to a lack of fall samples when trout-perch YOY would be more susceptible to the gear. However, at least some YOY were captured at all trawl stations.

Munuscong Bay trout-perch ranged from 22-127 mm in total length during 1984 (Table 25). Trout-perch captured at station 1 tended to be smaller, with most fish at 50-109 mm. Peaks in distribution were observed at 60-69 mm and 90-99 mm suggesting age classes of I and II based on previous data from the St. Marys River (Liston et al. 1985).

The length-weight relationship for trout-perch taken by trawl from Munuscong Bay in 1984 was:

$$\log W = -4.179 + 2.551 \log L \ (r^2 = 0.92)$$

where weight (W) is in grams and total length (L) is in millimeters. Apparently, young trout-perch did not grow as well as those captured in trawls of the St. Marys River system (Liston et al. 1985). The St. Marys River growth coefficient was as high as 2.80 in 1983 as compared to 2.55 in this study. According to past studies, trout-perch growth was much higher in the lower St. Marys River including stations in the eastern basin of Lake Munuscong.

Trout-perch may be one of the most important components of the Munuscong Bay system. Trout-perch are a significant part of the diet of many sport fish in the St. Marys River, including walleye, yellow perch, and northern pike (Borgeson 1983; Joyce 1983). In this study trout-perch represented over 12% of the demersal fish biomass.

Yellow perch. Yellow Perch was one of the three most abundant fishes taken by trawls in Munuscong Bay during 1984 (Table 26). They were present in over 87% of the trawl samples. Yellow perch was most abundant at station 4, followed by stations 2 (deep), 3, 7 (shallow), and 2 (shallow) (Table 24). Stations 8 and 1 had approximately equal catches of yellow perch, and the lowest catch occurred at station 7 (deep).

Few perch in spawning condition were taken in Munuscong Bay by trawl. Approximately 56% of the yellow perch were YOY. YOY yellow perch occurred at all stations and constituted almost all of the catch in late August.

Most yellow perch were less than 100 mm in total length (82.4%) indicating the large number of YOY fish in trawl collections (Table 26). Although the

Table 25. Length frequency composition (%) of trout-perch taken by trawls from Munuscong Bay, St. Marys River, 1984.

Length Interval (mm)	STATION																	
	1		2		2A		3		4		7		7A		8		combined	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
20-29	0	0	1	0.7	0	0	0	0	8	3.1	0	0	0	0	0	0	9	0.5
30-39	20	2.7	0	0	0	0	2	1.7	8	3.1	10	9.1	0	0	4	0.9	44	2.5
40-49	21	8.1	0	0	0	0	1	0.8	0	0	6	5.5	33	8.7	17	3.7	78	4.4
50-59	76	29.3	0	0	1	2.8	12	10.1	1	0.4	10	9.1	24	6.3	47	10.1	171	9.7
60-69	40	5.4	1	0.7	2	5.6	0	0	42	16.1	16	14.5	110	28.9	142	30.6	353	20.0
70-79	61	23.6	5	3.7	0	0	28	23.5	21	8.0	14	12.7	47	12.4	50	10.8	226	12.3
80-89	20	7.7	15	11.2	0	0	14	11.8	11	4.2	12	10.9	71	18.7	120	25.9	263	14.9
90-99	21	8.1	64	47.8	20	55.6	42	35.3	84	32.2	20	18.2	38	10.0	71	15.3	360	20.4
100-109	0	0	48	35.8	7	19.4	9	7.6	65	24.9	10	9.1	33	8.7	0	0	172	9.8
110-119	0	0	0	0	6	16.7	11	9.2	0	0	12	10.9	24	6.3	13	2.8	66	3.7
120-129	0	0	0	0	0	0	0	0	21	8.0	0	0	0	0	0	0	21	1.2
Total	259		134		36		119		261		110		380		464		1,763	

Table 26. Length frequency composition (%) of yellow perch taken by trawls from Munuscong Bay, St Marys River, 1984.

Length Interval (mm)	STATION 1		2		2A		3		4		7		7A		8		combined	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
40-59	13	59.1	86	61.4	111	50.9	104	50.2	156	67.0	2	66.7	78	49.1	15	57.7	565	56.1
60-79	3	13.6	14	10.0	15	6.9	19	9.2	2	5.2	1	33.3	19	11.9	6	23.1	89	8.8
80-99	0	0	16	11.4	54	24.8	20	9.7	54	23.2	0	0	32	20.1	0	0	176	17.5
100-119	5	227	6	4.3	15	6.9	0	0	4	1.7	0	0	6	3.8	0	0	36	3.6
120-139	0	0	6	4.3	1	0.5	0	0	0	0	0	0	2	1.3	0	0	9	0.9
140-159	0	0	1	0.7	9	4.1	15	7.2	3	1.3	0	0	14	8.8	0	0	42	4.2
160-179	1	4.5	7	5.0	7	3.2	30	14.5	4	1.7	0	0	8	5.0	4	15.4	61	6.1
180-199	0	0	4	2.9	5	2.3	0	0	0	0	0	0	0	0	0	0	9	0.9
200-219	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
220-239	0	0	0	0	0	0	11	5.3	0	0	0	0	0	0	1	3.8	12	1.2
240-259	0	0	0	0	0	0	4	1.9	0	0	0	0	0	0	0	0	4	0.4
260-279	0	0	0	0	1	0.5	0	0	0	0	0	0	0	0	0	0	1	0.1
280-299	0	0	0	0	0	0	4	1.9	0	0	0	0	0	0	0	0	4	0.4
Total	22		140		218		207		223		3		159		26		1,008	

majority of yellow perch at all stations in Munuscong Bay were less than 60 mm in length, station differences were apparent. For example, longer, older fish were relatively more abundant at stations 3 and 7 (shallow).

The length-weight relationship for yellow perch taken by trawl in Munuscong Bay during 1984 was:

$$\log W = -4.661 + 2.878 \log L \ (r^2 = 0.99)$$

where weight (W) is in grams and total length (L) is in millimeters. As compared to previous St. Marys River fish data, the yellow perch growth of Munuscong Bay was quite similar. Yellow perch are an important sport fish in the St. Marys River system and according to these results are significant both in terms of numbers and biomass. In addition to their direct economic importance, yellow perch provide some forage for other key sport fish including northern pike, rock bass, walleye and burbot (Borgeson 1983; Joyce 1983).

Johnny darter. Johnny darters occurred in over 87% of the trawl samples taken in Munuscong Bay during 1984. Abundance varied considerably by station (Table 27). Johnny darter were most abundant at station 7 (shallow), followed by stations 4 and 8. Catches at all other stations were relatively low.

Only one johnny darter, a female, was captured in spawning condition. This is consistent with previous sampling in other areas, where very few ripe darters were observed. Moreover, johnny darters are not completely recruited to trawl samples until after their first year so it was not unexpected that only a few YOY were captured.

Most johnny darters (69%) were 40-49 mm in total length (Table 27). Length composition varied somewhat between stations. Collections at stations 2, 2 (shallow), and 4 tended to have larger johnny darters compared to the other trawl stations . The greatest concentration of YOY johnny darters (less than 30 mm TL) was at station 3, suggesting that this site may be a prime spawning and nursery area.

The length-weight relationship for johnny darters taken by trawl in Munuscong Bay in 1984 was:

$$\log W = -3.394 + 2.085 \log L \ (r^2 = 0.61)$$

where weight (W) is in grams and total length (L) is in millimeters. The regression value of 2.09 was somewhat lower than values obtained in trawl sampling of the St. Marys River. It is possible that growth rate was reduced in 1984 and not only in Munuscong Bay. Johnny darters are prey to several important sport fish in the St. Marys River, including yellow perch, northern pike and rock bass (Whalen 1980; Borgeson 1983; Joyce 1983).

Spottail shiner. Spottail shiners comprised over 18% of the total trawl catch in Munuscong Bay during 1984, and occurred in over 81% of all trawl samples (Table 28). The species was most abundant at station 7 (shallow) where over 44% of the total catch was taken (Table 24). CPE of spottail shiner was generally similar (21.5-43.0) at stations 2, 2 (shallow), 3, 4, and 8. CPE at

Table 27. Length frequency composition (%) of johnny darters taken by trawl from Munuscong Bay, St. Marys River, 1984.

Length Interval (mm)	STATION 1		2		2A		3		4		7		7A		8		combined	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
20-24	0	0	0	0	0	0	1	2.9	0	0	0	0	0	0	0	0	1	0.1
25-29	1	9.1	0	0	6	17.6	3	8.8	4	5.5	1	9.1	4	3.8	0	0	19	5.6
30-34	0	0	0	0	2	5.9	6	17.6	1	1.4	2	18.2	8	7.6	6	10.7	25	7.4
35-39	2	18.2	1	6.7	0	0	9	26.5	0	0	3	27.3	10	9.5	0	0	25	7.4
40-44	3	22.8	3	20.0	1	2.9	5	14.7	30	41.1	4	36.4	50	47.6	43	76.8	139	41.0
45-49	4	36.4	4	26.7	13	38.2	8	23.5	29	39.7	0	0	29	27.6	7	12.5	94	27.7
50-54	1	9.1	5	33.3	6	17.6	2	5.9	9	12.3	1	9.1	4	3.8	0	0	28	8.3
55-59	0	0	2	13.3	6	17.6	0	0	0	0	0	0	0	0	0	0	8	2.4
Total	11		15		34		34		73		11		105		56		339	

BLANK PAGE

BLANK PAGE

BLANK PAGE

Table 28. Length frequency compostion (%) of spottail shiners taken by trawl from Munuscong Bay, St. Marys River, 1984.

Length Interval (mm)	STATION 1		2		2A		3		4		7		7A		8		combined	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
20–29	2	8.0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.2	0	0
30–39	2	8.0	0	0	0	0	0	0	1	0.6	0	0	0	0	0	0	3	0.3
40–49	4	16.0	0	0	27	18.4	0	0	6	3.5	0	0	6	1.2	11	12.6	54	4.8
50–59	4	16.0	3	2.7	0	0	0	0	39	22.5	1	25.0	255	51.0	41	47.1	343	30.2
60–69	3	12.0	43	38.4	35	23.8	26	29.5	100	57.8	0	0	191	38.2	22	25.3	420	37.0
70–79	1	4.0	41	36.6	55	37.4	37	42.0	18	10.4	1	25.0	21	4.2	0	0	174	15.3
80–89	4	16.0	22	19.6	2	1.4	13	14.8	0	0	0	0	0	0	1	1.1	42	3.7
90–99	4	16.0	2	1.8	28	19.0	10	11.4	5	2.9	2	50.0	18	3.6	1	1.1	70	6.2
100–109	1	4.0	1	0.9	0	0	2	2.3	4	2.3	0	0	9	1.8	11	12.6	28	2.5
Total	25		112		147		88		173		4		500		89		1,134	

stations 1 and 7 (deep) were lowest (<10 CPE). Overall catch peaked about mid-summer (late July) and declined in August.

No spottail shiners in spawning condition were taken by trawl from Munuscong Bay in 1984. Females outnumbered males by nearly 6 to 1. Only five young-of-the-year spottail shiners were captured in 1984 trawl samples; all but one of those was taken from station 1. With the exception of station 1, length frequencies at each station were quite similar. Populations at those stations were made up almost entirely of fish greater than 50 mm in total length (Table 28). In contrast, the spottail shiners caught at station 1 were distributed fairly evenly from 20 mm to 109 mm TL.

The length-weight relationship for spottail shiners taken by trawl in Munuscong Bay in 1984 was:

$$\log W = -4.625 + 2.788 \log L \ (r^2 = 0.95)$$

where weight (W) is in grams and total length (L) is in millimeters.

Spottail shiners are an abundant forage species in the St. Marys River system, and are an important prey item of walleye, northern pike, rock bass and burbot (Borgeson 1983; Sargent 1982).

Mimic shiner. Mimic shiners comprised over 18% of the total trawl catch in Munuscong Bay during 1984, and occurred in 28% of the trawl samples (Table 24). Nearly all mimic shiners were captured on the final sampling date in 1984 (18 August). On that date over 97% were captured at stations 2, 2A, 3, and 4, suggesting mimic shiner may have migrated into the northcentral portion of the bay from down-bound west Neebish Island channel.

No mimic shiners in spawning condition were taken by trawl. According to Becker (1983) the breeding site and spawning habits of mimic shiners are poorly known, but it is suggested that they broadcast eggs over weeds in deep, littoral areas throughout the summer.

Mimic shiners ranged from 37-64 mm total length with peaks in length composition at 45-49 mm and 55-59 mm (Table 29). At stations where significant numbers were caught, as at 2A, a fairly balanced adult population was suggested. There was no evidence of higher growth rates or low mortality as hypothesized for the lower St. Marys River (Liston et al. 1985). The length-weight relationship for mimic shiner taken from trawl data of Munuscong Bay in 1984 was:

$$\log W = -4.310 + 2.660 \log L \ (r^2 = 0.90)$$

where weight (W) is in grams and total length (L) is in millimeters.

Mimic shiners in the St. Marys River were preyed upon by rock bass (Joyce 1983). They may also be taken by other predatory fish in the system and by piscivorous birds such as the blue heron (Becker 1983).

Table 29. Length frequency composition (%) of mimic shiners taken by trawls from Munuscong Bay, St. Marys River, 1984.

Length Interval (mm)	STATION 1		2		2A		3		4		7		7A		8		combined	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
35-39	1	25.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.1
40-44	1	25.0	0	0	76	10.0	0	0	0	0	0	0	4	20.0	1	25.0	82	7.2
45-49	0	0	34	20.0	228	30.0	0	0	54	50.0	0	0	8	40.0	2	50.0	326	28.6
50-54	1	25.0	0	0	228	30.0	15	20.0	0	0	0	0	0	0	0	0	244	21.4
55-59	1	25.0	34	20.0	152	20.0	30	40.0	54	50.0	0	0	8	40.0	0	0	279	24.5
60-64	0	0	102	60.0	76	10.0	30	40.0	0	0	0	0	0	0	1	25.0	209	18.3
Total	4		170		760		75		108		0		20		4		1,141	

Other species. Despite a large population of adult walleye in Munuscong Bay, few walleye YOY were captured in trawls (Table 23). A total of 5 YOY were taken in 1984, and of these four (80%) were captured at station 1 (Table 24). However, all of the black crappie captured by trawls in 1984 were young-of-the-year. Of these, 97% were also taken at station 1. Approximately 71% of rock bass taken by trawls in 1984 were YOY; 47% were found at station 2, 23% at station 2A, 12% at station 3, and 9% at stations 1 and 7 (shallow).

Small-Mesh Trap Nets

A total of 6,021 fish representing 25 species were collected in small-mesh trap nets from July through August. Total catch was dominated by the families Cyprinidae (35.3%), Percidae (32.6%) and Centrarchidae (26.8%) (Table 30). Yellow perch was clearly the most abundant species at 31.8% of the total catch. Black crappie was also common (18.6%), followed by a wide diversity of less abundant species including several cyprinid species (emerald shiner, Pimephales, spottail shiner, golden shiner, common shiner, sand shiner and mimic shiner), rock bass, brown bullhead, pumpkinseed sunfish, smallmouth bass, and walleye. The total fish biomass of the collection was approximately 1.45 x 10^5 g. Brown bullhead represented 64% of this weight, while white sucker (8.9%), bowfin (8.0%), and northern pike (3.5%) comprised much of the remainder. Over 90% of the catch was young-of-the-year or yearling fishes. Brown bullheads were the only predominantly adult species.

Highest numerical catch (73% of total) was obtained in August as compared to July. Spottail shiner, black crappie, brown bullhead, and pumpkinseed sunfish were more prevalent in July whereas yellow perch, Pimephales sp., rock bass, and common shiners gained in dominance during August. Moreover, those species that were present were more frequent in the August catch, suggesting increased dispersal regardless of changes in abundance. Fish biomass was somewhat higher in the July catch, with totals in 9.3 x 10^4 and 5.2 x 10^5 in July and August, respectively. The biomass of individual species generally increased from July to August with largest gains attributable to brown bullheads.

Largest catch per effort (560-605 fish per 24 hour set) was found at stations 1BS and 1S, located near station 1 in previous sampling of Munuscong Bay (Figure 8). Sampling site 8S was the least productive site with lowest catch (9 fish /set). Other stations ranged from 157-312 fish caught per 24 hour set. Species diversity was highest near Maple Point (station 5S) with 21 species compared to 16 at most other localities. Based on these observations, young fishes may be particularly concentrated around the protected shorelines of western Munuscong Bay. The abundance of fishes near station 1 may be related to the influence of the Munuscong and Little Munuscong Rivers. Many species of fish may rely on such inflowing tributaries as feeding or refuge areas.

Overall, it appears that the nearshore zone of Munuscong Bay harbors a wide diversity and/or relatively high abundance of warm and cool water fishes, particularly cyprinids, centrarchids, and percids. These littoral areas are likely essential to the survival and well being of the young-of-the-year of many St. Marys species.

Large-Mesh Trap Nets

A total of 2,472 fishes, representing 19 species, were collected at all stations from April through September with large-mesh trap nets (Table 32). Total catch in Munuscong Bay was dominated by walleye and white sucker which when combined comprised two-thirds of the total number. Channel catfish was the third most abundant fish in the catch contributing 9.1%. Some 16 other species made up the remaining 23% of the total catch.

The greatest total catch occurred in April (Table 32) which may be attributed to large numbers of walleye and white sucker in spawning condition. The second largest catch was in July and was also clearly dominated by walleye and white sucker. Total catch during other months was considerably lower, and ranged from 136-356 fish. Burbot and lake herring were primarily collected in early spring. Northern pike catches peaked in spring and early summer, but persisted in lower numbers through late summer. Centrarchids were relatively scarce in spring and early summer, but became abundant in late summer as water temperatures warmed.

Greatest total catch occurred at station 5L near Steamboat Island with the remaining catch distributed almost equally among stations 2L, 3L, and 8L (Table 33). Large numbers of walleye were responsible for the sizeable catch at station 5L particularly in April. This is a rocky area which may attract many gravel spawners including walleye and white suckers in April and silver and shorthead redhorse in May (Scott and Crossman 1973). This area may be an important walleye spawning ground as several larvae were also collected in push nets at this station.

Walleye were also prevalent around station 8L, perhaps reflecting movements downriver and into feeding habitats in June and July. Liston et al. (1985) captured the majority of the walleye in a station near Roach Point suggesting this area continues to be significant to St. Marys walleye populations. The abundance of spottail and emerald shiners found in small mesh trap net collections at station 8 may serve as a forage base for these walleye.

Other species which were tolerant of water turbidity were also common at the trap net stations on the southern shore (5L and 8L). For example, channel catfish, silver redhorse, shorthead redhorse, and pumpkinseed sunfish were more abundant at these stations. White sucker, black crappie, yellow perch, and burbot appeared to prefer areas of lower turbidity and cooler water close to the navigation channels. White sucker, black crappie, and yellow perch were predominantly captured at station 2 where the St. Marys River enters Munuscong Bay. Station 2 was the most diverse of all sample sites with 16 species, 11 of which were present in moderate abundance.

Munuscong Bay trap net collections were lower both in terms of CPE and diversity when compared to previous sampling of the St. Marys River. A low species diversity was probably due to reduced sample size and may not be a reflection of an actual paucity of fish. Walleye were more abundant than in past trap net collections. The hypothesis put forward by Liston et al. (1985) that walleye may rely on tributary and off-channel areas seems to be supported by the Munuscong Bay data. The predominance of adult white suckers was also

Table 30. Total numbers and percent composition of fishes caught in small-mesh trap nets set in Munuscong Bay, of the St. Marys River, 1984.

Species	Total Number	% Total Number	% Frequency Occurrence
Yellow perch	1,912	31.8	67
Black crappie	1,119	18.6	50
Emerald shiner	595	9.9	61
Pimephales	536	8.9	67
Spottail shiner	535	8.9	78
Rock bass	281	4.7	72
Golden shiner	232	3.9	72
Brown bullhead	213	3.5	67
Common shiner	155	2.6	44
Pumpkinseed	153	2.5	56
Smallmouth Bass	60	1.0	67
Sand shiner	60	1.0	17
Walleye	48	0.8	56
Gizzard shad	29	0.5	22
Log perch	18	0.3	17
White sucker	18	0.3	61
Mimic shiner	15	0.3	11
Trout perch	12	0.2	22
Silver redhorse	11	0.2	11
Northern pike	8	0.1	33
Bowfin	5	0.1	22
Shorthead redhorse	3	0.0	17
Bluegill	1	0.0	6
Silver lamprey	1	0.0	6
Longnose gar	1	0.0	6
TOTAL	6,021		

Table 31. Comparison of the numbers and percent composition of fishes caught in July and August in small-mesh trap nets set in Munuscong Bay, St. Marys River, 1984.

species	JULY total number	JULY %total number	JULY % freq. occurrence	AUGUST total number	AUGUST %total number	AUGUST %freq. occurrence
Yellow perch	379	20.3	44	1,533	36.9	89
Black crappie	434	23.2	11	685	16.5	89
Emerald shiner	214	11.5	44	381	9.2	78
Pimephales spp.	50	2.7	44	486	11.7	89
Spottail shiner	396	21.2	67	139	3.3	89
Rock bass	11	0.6	44	270	6.5	100
Golden shiner	56	3.0	67	176	4.2	78
Brown bullhead	149	8.0	89	64	1.5	44
Common shiner	4	0.2	33	151	3.6	56
Pumpkinseed	88	4.7	33	65	1.6	78
Smallmouth bass	8	0.4	44	52	1.3	89
Sand shiner	23	1.2	22	37	0.9	11

Table 32. Numbers of fish collected in large-mesh trap nets in Munuscong Bay, St. Marys River, 1984.

Species	April	May	June	July	Aug	Sept	Total	%
Walleye	470	129	33	189	67	42	930	37.6
White sucker	237	104	60	210	76	45	732	29.6
Channel catfish	127	10	7	46	2	32	224	9.1
Silver redhorse	23	48	3	10	10	36	130	5.3
Northern pike	1	31	14	39	9	6	100	4.0
Rock bass	0	8	1	11	34	26	80	3.2
Black crappie	0	1	3	20	10	34	68	2.8
Shorthead redhorse	3	11	8	16	10	13	61	2.5
Yellow perch	12	6	4	19	7	6	54	2.2
Smallmouth bass	0	1	1	3	18	14	37	1.5
Brown bullhead	1	1	1	6	5	1	15	0.6
Pumpkinseed	0	0	0	0	10	1	11	0.4
Burbot	7	2	0	0	0	0	9	0.4
Common carp	0	2	1	5	0	1	9	0.4
Lake herring	3	2	0	0	0	1	6	0.2
Lake whitefish	0	0	0	1	0	1	2	0.1
Longnose sucker	2	0	0	0	0	0	2	0.1
Bowfin	1	0	0	0	0	0	1	<0.1
Muskellunge	0	0	0	0	0	1	1	<0.1
Total	887	356	136	575	258	260	2,472	

Table 33. Numbers of fishes collected with large-mesh trap nets at various stations in Munuscong Bay, St. Marys River, 1984.

	Station			
Species	2L	3L	5L	8L
Walleye	82	13	579	256
White sucker	186	272	196	78
Channel catfish	24	36	84	80
Silver redhorse	45	9	51	25
Northern pike	18	39	33	10
Rock bass	35	5	30	10
Black crappie	67	1	0	0
Shorthead redhorse	12	1	38	10
Yellow perch	26	15	5	8
Smallmouth bass	15	1	15	6
Brown bullhead	9	2	2	2
Pumpkinseed	2	0	9	0
Burbot	0	7	0	2
Common carp	1	3	4	1
Lake herring	0	0	4	2
Lake whitefish	0	2	0	0
Longnose sucker	0	0	1	1
Bowfin	1	0	0	0
Muskellunge	1	0	0	0
Total	524	406	1,051	491

generally true for other sites along the St. Marys River and probably does not indicate a uniqueness of the Munuscong Bay habitat (Liston et al. 1985). CPE of yellow perch and burbot were similar to those of other years while CPE was relatively low for brown bullhead.

Length frequencies for important species collected by the large-mesh trap nets are given in Tables 34-41.

Mark/recapture data. The total number of fish tagged and released from large trap nets in Munuscong Bay during 1984 was 1,079 (Table 42). Walleye comprised 58% of the tagged fish while channel catfish made up 13%. No other species made up more than 10% of the total number tagged. Although white suckers comprised nearly 30% of the large trap net catch none were tagged as few were recovered in past studies (Liston et al. 1985).

A total of 35 (3.2%) fish tagged in 1984 were recaptured as of March 1986. Nearly 71% of the fish were released at station 5 or 8 and fully 80% of the recaptured fish had been released at these stations (Table 43). Only three of the fish were recaptured in experimental gear.

Over 87% of the walleye tagged in 1984 were released at stations 5 and 8. Of these, a total of 21 were captured by anglers as of March 1986. None of the walleye were recaptured by experimental gear during 1984. All of the recaptured fish had been tagged at station 5 or 8 (Table 43). Three of the walleye had traveled approximately 50 km to Scott's Bay of Drummond Island or to the North Channel of Lake Huron. Two of these fish had migrated downriver within the year after being tagged in the spring. This most likely represents the dispersal of fish from spawning areas in Munuscong Bay as previously noted by Liston et al. (1985). The remainder of the recaptured walleye were caught within 4 km of the release site, considerably less than the average of 14 km traveled by walleye tagged in 1982 (Liston et al. 1985).

A total of 145 channel catfish were tagged and released in Munuscong Bay during 1984, and three were later recaptured. One was recaptured by large trap nets about 3 km from the release site after 72 days. A second was caught by an angler near Milford Island in the North Channel of Lake Huron (about 50 km) after 11 days and the third traveled south approximately 320 km to Saginaw Bay in 519 days.

Four of 88 northern pike tagged in 1984 were recaptured as of March 1986. All were recaptured by anglers and only one provided information regarding point of capture. This fish was recaptured near Moon Island in Munuscong Bay, near the point of release 313 days earlier. Previous tag and recapture data have shown that northern pike are relatively sedentary with few fish traveling great distances in the St. Marys River system (Liston et al. 1985).

Two rock bass of the 66 tagged in 1984 were recaptured. One was caught by an angler in Munuscong Bay after being at large 290 days. Liston et al. (1985) found that rock bass were quite sedentary in the St. Marys River System, moving an average of only 2 km during the 1982-83 study. One yellow perch of the 49 released had been caught as of March 1986. It is not known where the fish was recaptured. Two of 45 black crappie tagged in 1984 were recaptured as of March

Table 34. Length-frequency of walleye caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
220 - 239	2	0.3
240 - 259	5	0.8
260 - 279	8	1.3
280 - 299	5	0.8
300 - 319	16	2.5
320 - 339	18	2.8
340 - 359	35	5.5
360 - 379	38	6.0
380 - 399	46	7.2
400 - 419	43	6.8
420 - 439	60	9.4
440 - 459	64	10.0
460 - 479	58	9.1
480 - 499	46	7.2
500 - 519	30	4.7
520 - 539	31	4.9
540 - 559	22	3.5
560 - 579	23	3.6
580 - 599	23	3.6
600 - 619	14	2.2
620 - 639	13	2.0
640 - 659	11	1.7
660 - 679	12	1.9
680 - 699	8	1.3
700 - 719	3	0.5
720 - 739	2	0.3
740 - 759	0	0.0
760 - 779	0	0.0
780 - 799	1	0.2

Grand total:	637
Length range:	222 - 785

Table 35. Length-frequency of channel catfish caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
320 - 339	1	0.7
340 - 359	0	0.0
360 - 379	1	0.7
380 - 399	0	0.0
400 - 419	2	1.4
420 - 439	11	7.5
440 - 459	14	9.6
460 - 479	27	18.5
480 - 499	28	19.2
500 - 519	27	18.5
520 - 539	17	11.6
540 - 559	5	3.4
560 - 579	4	2.7
580 - 599	2	1.4
600 - 619	3	2.1
620 - 639	2	1.4
640 - 659	0	0.8
660 - 679	1	0.7
680 - 699	0	0
700 - 719	0	0
720 - 739	0	0
740 - 759	0	0.0
760 - 779	0	0.0
780 - 799	0	0.0
800 - 819	0	0.0
820 - 839	1	0.7
Grand total:	146	
Length range:	321 - 825	

Table 36. Length-frequency of northern pike caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
360 - 379	2	2.3
380 - 399	4	4.5
400 - 419	4	4.5
420 - 439	5	5.7
440 - 459	10	11.4
460 - 479	9	10.2
480 - 499	19	21.6
500 - 519	11	12.5
520 - 539	6	6.8
540 - 559	4	4.5
560 - 579	1	1.1
580 - 599	5	5.7
600 - 619	2	2.3
620 - 639	2	2.3
640 - 659	2	2.3
660 - 679	1	1.1
680 - 699	0	0.0
700 - 719	0	0.0
720 - 739	0	0.0
740 - 759	0	0.0
760 - 779	1	1.1

Grand Total: 88

Length Range: 365 - 760

Table 37. Length-frequency of white suckers caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
240 - 259	2	0.6
260 - 279	0	0
280 - 299	1	0.3
300 - 319	2	0.6
320 - 339	1	0.3
340 - 359	6	1.8
360 - 379	12	3.7
380 - 399	47	14.6
400 - 419	65	21.1
420 - 439	75	23.2
440 - 459	55	17.0
460 - 479	33	10.2
480 - 499	17	5.3
500 - 519	6	1.8
520 - 539	1	0.3
Grand total:	323	

Table 38. Length-frequency of rock bass caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
170 - 179	1	1.5
180 - 189	1	1.5
190 - 199	3	4.4
200 - 209	6	8.8
210 - 219	8	11.8
220 - 229	8	11.8
230 - 239	4	5.9
240 - 249	6	8.8
250 - 259	7	10.3
260 - 269	12	17.6
270 - 279	3	4.4
280 - 289	5	7.4
290 - 299	0	0.0
300 - 309	0	0.0
310 - 319	0	0.0
320 - 32[illegible]	0	0.0
330 - 33[illegible]	0	0.0
340 - 349	1	1.5
350 - 359	1	1.5
360 - 369	0	0.0
370 - 379	1	1.5
380 - 389	0	0.0
390 - 399	1	1.5

Grand total: 68

Length rage: 171 - 391

Table 39. Length-frequency of yellow perch caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
180 - 189	1	2.0
190 - 199	4	8.2
200 - 209	3	6.1
210 - 219	4	8.2
220 - 229	2	4.1
230 - 239	3	6.1
240 - 249	4	8.2
250 - 259	1	2.0
260 - 269	3	6.1
270 - 279	2	4.1
280 - 289	3	6.1
290 - 299	2	4.1
300 - 309	4	8.2
310 - 319	3	6.1
320 - 329	2	4.1
330 - 339	4	8.2
340 - 349	3	6.1
350 - 359	1	2.0
Grand total:	49	
Length rage:	182 - 350	

Table 40. Length-frequency of black crappie caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
200 - 209	1	2.2
210 - 219	0	0.0
220 - 229	0	0.0
230 - 239	0	0.0
240 - 249	1	2.2
250 - 259	0	0.0
260 - 269	2	4.3
270 - 279	2	4.3
280 - 289	1	2.2
290 - 299	3	6.5
300 - 309	0	0.0
310 - 319	4	8.7
320 - 329	12	26.1
330 - 339	8	17.4
340 - 349	9	19.6
350 - 359	3	6.5
Grand total:	46	
Length rage:	207 - 350	

Table 41. Length-frequency of smallmouth bass caught in large trap nets set in Munuscong Bay, 1984.

Length	Number	%
180 - 199	1	3.0
200 - 219	0	0.0
220 - 239	0	0.0
240 - 259	1	3.0
260 - 279	0	0.0
280 - 299	4	12.1
300 - 319	6	18.2
320 - 339	5	15.2
340 - 359	6	18.2
360 - 379	3	9.1
380 - 399	3	9.1
400 - 419	2	6.1
420 - 439	0	0.0
440 - 459	2	6.1

Grand total:	33
Length range:	197 - 446

Table 42. Tag, release, and recapture data for fish collected with large-mesh trap nets in Munuscong Bay, 1984.

Species	Total Captured	% Total	Number Tagged	Number Recaps	% Recovery
Walleye	930	37.6	628	21	3.3
White sucker	732	29.6	0	0	-
Channel catfish	224	9.1	145	3	2.1
Silver redhorse	130	5.2	1	0	0
Northern pike	100	4.0	88	4	4.5
Rock bass	80	3.2	66	2	3.0
Black crappie	68	2.8	45	2	4.4
Shorthead redhorse	61	2.5	0	0	-
Yellow perch	54	2.2	49	1	2.0
Smallmouth bass	37	1.5	33	1	3.0
Brown bullhead	15	0.6	6	0	0
Pumpkinseed	11	0.4	10	0	0
Burbot	9	0.4	6	1	16.7
Common carp	9	0.4	0	0	-
Lake herring	6	0.2	1	0	0
Lake whitefish	2	0.1	0	0	-
Longnose sucker	2	0.1	0	0	-
Bowfin	1	<0.1	0	0	-
Muskellunge	1	<0.1	1	0	0
TOTAL	2,472	100.0	1079	35	3.2

Table 43. Numbers of fish tagged and released after capture in large-mesh trap nets at each of four stations in Munuscong Bay during 1984 (numbers recaptured in parenthesis).

	STATION				
Species	2L	3L	5L	8L	Total
Walleye	68	10	307(12)	243(9)	628(21)
Channel catfish	19	30	18(1)	78(2)	145(3)
Northern pike	16(1)	38(1)	25(2)	9	88(4)
Rock bass	23(1)	4	29(1)	10	66(2)
Yellow perch	25(1)	13	3	8	49(1)
Black crappie	45(2)	0	0	0	45(2)
Smallmouth bass	11	1	15	6(1)	33(10)
Pumpkinseed	1	0	9	0	10
Brown bullhead	3	1	0	2	6
Burbot	0	4(1)	0	2	6(1)
Muskellunge	1	0	0	0	1
Lake herring	0	0	1	0	1
Silver redhorse	0	0	0	1	1
Total	212(5)	101(2)	407(16)	359(12)	1,079(44)

1986. One was taken in a trap net at the release site after 27 days, and one was caught by an angler about 6 km away from the release site after 276 days. Only 3 black crappie had been tagged in previous work and none were recaptured (Liston et al. 1985). One smallmouth bass had been recaptured as of March 1986 after being tagged in 1984, although recapture site was not given. One burbot was recaptured approximately 4 km from the release site after 276 days at large. Previously recaptured burbot had moved from 5 to 15 km, and exhibited both upstream and downstream movements (Liston et al. 1985).

SUMMARY

The Department of Fisheries and Wildlife, Michigan State University has conducted studies during 1979-1984 of environmental baseline conditions of the St. Marys River. These studies were performed to help assess the potential impacts of alternatives being considered for extended season navigation. In 1984, sampling effort was concentrated in Munuscong Bay to develop baseline data for assessing potential impacts to the off-channel lentic habitats which were not previously studied in much detail. Baseline data were developed on winter sedimentation, turbidity, dissolved oxygen, water temperature, benthic macroinvertebrates, and fish (larval, juvenile, and adult).

Munuscong Bay was chosen for its general accessibility, proximity to the navigation channel, and high value regarding sports fishing. This body of water covers over 4,500 hectares and includes a wide diversity of habitats. The St. Marys River and downbound navigation channel enter the bay at the northeast end. The western shore is characterized by shallow, silty, vegetated bays and receives the inflow of the Munuscong and Little Munuscong Rivers. Emergent plants encircle the shoreline with primarily muddy substrates across the shallow bay bottom. However, rocky outcroppings are prevalent around the Moon Islands, a dredge material disposal site south and west of the navigation channel and also around the southern shore of Munuscong Bay.

PHYSICAL AND CHEMICAL ASPECTS

Physical, chemical, and biological samples were collected between January and September of 1984. In general, sampling was conducted across four major areas including stations along the western shore, the northern shore near the navigation channel inflow, at mid-bay, and along the rocky shore of the southern bay.

Water temperatures warmed gradually from 3-7 °C in April to peaks of 20-24° C in August, then began to decline in late August through early September. Water temperatures were generally highest at nearshore and littoral stations. This nearshore/offshore temperature difference may play an important role in the seasonal distribution of aquatic fauna. Dissolved oxygen levels were highest at 9 to 13 mg/l in late April, and fell gradually to 7-10 mg/l by late August. Dissolved oxygen was always above EPA recommended levels for maintaining healthy fish populations.

Water turbidities ranged from 1.7 to 86 NTU with highest average values measured in early spring likely due to increased runoff and tributary inputs. The navigational channel did not seem to influence turbidity. Rather, turbidity appeared to be primarily a function of wind-induced disturbances along the unconsolidated shallows of western Munuscong Bay. Sediment traps composed of 30.5 cm x 2.5 cm diameter cylinders were used to collect winter sedimentation data throughout Munuscong Bay. Sedimentation was collected over two exposure periods in February and March. Sedimentation rates ranged from approximately 120 to 8,000 mg/day/m^2 with highest values obtained in the second exposure period. Apparently, a slightly higher sediment load occurred in March than in February of 1984.

The most notable seasonal increase in sedimentation rates occurred at stations near the shipping channel. However, sedimentation and turbidity were lower near the navigation channel than off the inflow of the Munuscong and Little Munuscong Rivers. Examination of the size-range of sedimented particles and their settling rates indicates that although little deposition occurred near the downbound channel, much of the sediment load was fine clay which could remain suspended or settle out in slower moving, back-water areas.

BENTHIC MACROINVERTEBRATES

Benthic invertebrate samples were collected on 4 May, 1984. A total of 24 Ekman and 30 PONAR grab samples were used to collect samples across 10 open water and 4 inshore sample sites. Estimates of total benthic macroinvertebrate abundance ranged from 2,756-24,397/m^2 and 3,168-27,456/m^2 in PONAR and Ekman dredge samples, respectively. Ekman samples were generally much more variable in benthic invertebrate abundance and may be related to vegetational structure. PONAR samples, however, exhibited a general pattern of higher benthic densities at stations of higher turbidity. Benthic abundance was generally highest at stations furthest from the river channel. Although this pattern may reflect navigational effects, it may also simply imply higher habitat stability and vegetational structure in the shallows of the western basin. Moreover, benthic diversity and abundance was also reduced in the stations off the Munuscong and Little Munuscong Rivers where oligochaetes and chironomids predominated.

Comparisons with other local waters of the St. Marys River shows Munuscong Bay benthos densities to be generally less than upstream and greater than downstream areas. As suggested in previous reports (Liston et al. 1985) the size of substrate particles and the rates of sedimentation may influence this pattern.

Fourty-six benthic taxa were collected in Munuscong Bay. Important benthos taxa included Chironomidae larvae, Oligochaeta, Ephemeroptera (three genera), Trichoptera (ten genera), Gastropoda (9 genera), Pelecypoda (3 genera), Amphipoda (3 genera), Isopoda (2 genera), and Ostracoda. As compared to previous sampling, Munuscong Bay exhibited a less diverse benthic community. However, these differences may be explained in part by the larger sample size and greater diversity of gears used in other years.

FISH LARVAE

Larval fish were sampled at night at eight stations in Munuscong Bay approximately biweekly from April through August, 1984. Channel and deep waters were sampled with 1.0 m diameter plankton tow nets (52 samples), shallow open-water areas were sampled with 0.5 m diameter plankton push nets (139 samples), and shallow littoral areas in macrophyte beds were sampled with 21 x 24 cm rectangular mouth plankton pull nets (54 samples). All plankton nets were 351 u mesh nitex, and flowmeters were attached for determining volumes filtered.

Total larval fish density was highest in off-channel stations along the western and southern shores of Munuscong Bay. Total densities were also highest for pull net samples taken in the shallow, densely vegetated nearshore zone. As in other parts of the St. Marys River, macrophyte beds appear to be the prime spawning and nursery areas for many species of fish.

Some 33 taxa representing 12 families were identified from 6,731 larval fish collected in Munuscong Bay. Twelve taxa were considered common (<100 individuals collected) but only three species (rainbow smelt, emerald shiner, and yellow perch) were clearly dominant, comprising over 60% of the total catch. The remaining 9 taxa considered common, in order of decreasing abundance, were: Cyprinidae, spottail shiner, black crappie, logperch, common carp, *Lepomis* spp., gizzard shad, johnny darter, and lake herring.

Seasonal trends in the appearance and abundance of larval species were apparent and as expected based on previous studies. Early hatching larvae included coregonids and burbot. Late spring larvae were comprised mainly of rainbow smelt and yellow perch. Greatest larval densities were observed later in summer when Cyprinidae (spottail and emerald shiner), Percidae (logperch and johnny darter), and Centrarchidae (*Lepomis* spp. and black crappie) were prevalent.

The larval fish species composition of Munuscong Bay did not differ substantially from previous studies of the St. Marys River. Inshore species, particularly cyprinids, were somewhat more abundant. However, Munuscong Bay appeared to harbor both inshore and offshore species assemblages as documented for the bays and channels in other sample years. Munuscong Bay's larval fish diversity may be partially attributable to the diversity of habitats available for spawning and feeding activity. While extensive macrophyte beds harbor high densities of carp, emerald shiner, and various centrarchids, the inflowing tributaries of the Munuscong and Little Munuscong River and downbound channel may provide suitable habitats for coolwater spawners such as the rainbow smelt, yellow perch, lake herring and walleye.

JUVENILE AND ADULT FISH

Adult and juvenile fishes were sampled with trawls, and small-mesh trap nets and large-mesh trap nets. A total of 32 nighttime trawls were completed at eight sample sites in Munuscong Bay from May through August, 1984. A total of 6,178 fish were collected representing 27 species and 12 families. Cyprinidae and Percidae were most widely represented with five species each. Trout-perch, yellow perch, mimic shiner, and spottail shiner dominated the demersal community and collectively comprised nearly 85% of the catch. Total catch was somewhat higher in sheltered areas. Length-frequencies and length/weight relationships for major species are provided for further comparisons. The Munuscong Bay demersal community was similar to that described in other areas of the lower St. Marys River System.

Small-mesh trap nets were deployed inshore at eight sample sites with nine sets completed in both July and August. A total of 6,021 fish representing 25 species were collected and identified. Total catch was dominated by Cyprinidae (35.3%), Percidae (32.6%), and Centrarchidae (26.8%). Yellow perch was clearly the dominant species (31.8%) followed by black crappie (18.6%) and over six cyprinid species, rock bass, brown bullhead, pumpkinseed, smallmouth bass and walleye. Of the 12 most common species, over 95% were young-of-the-year or yearlings. Highest catch was found around stations near the inflow of tributaries, which may illustrate the importance of tributaries as feeding and schooling areas for young fishes.

Large-mesh trap nets were set monthly at four stations from April through September. A total of 2,472 fishes representing 19 species were collected. Total catch was dominated by adult walleye and white sucker. Walleye were particularly abundant during early spring around the spoil site and southern rocky shore of Munuscong Bay. In late July, walleye congregated in a shallow-water, vegetated bay near sites where walleye were collected in previous studies (Liston et al. 1985). Walleye distribution appeared to be related to higher turbidities as measured along the southern shore of Munuscong Bay. White sucker were ubiquitous but were in highest abundance near the navigation channel. Channel stations also excelled in catches of yellow perch and black crappie. Nearshore stations exhibited higher catches of walleye, channel catfish, pumpkinseed sunfish, lake herring, and redhorse. Munuscong Bay appeared to harbor a less diverse adult fish community compared to other St. Marys River areas. However, a reduced sample size and season in 1984 may have been responsible for this observation. Adult walleye were in greater abundance in large trap net collections from Munuscong Bay compared to similar collections from other parts of the St. Marys River system. A total of 1,079 adult fish were tagged and released from trap net collections, and 38 (3.2%) had been recovered through March, 1986.

The Munuscong Bay data were taken in relation to the proposed extension of the navigation season to January 31 ± 2 weeks, and provide a quantitative description of Munuscong Bay resources heretofore unavailable. Based upon these studies, Munuscong Bay supports important and diverse benthic invertebrate and fish communities. Concerns should be given to potential physical changes of ice formation and under-ice disruption from passing ships. Also, if extended season shipping results in suspension of sediments upstream from Munuscong Bay, these materials could be flushed into the Bay and may increase sedimentation and winter turbidity levels. The effects of these potential changes on the Munuscong Bay biota are not known.

LITERATURE CITED

Amundrud, J.R., D.J. Faber, and A. Keast. 1974. Second succession of free swimming perciform larvae in Lake Opinicon, Ontario. J. Fish Res. Board Can. 31:1661-1665.

Allen, J.D. 1975. The distributional ecology and diversity of benthic insects in Cement Creek, Colorado. Ecol. 56:1040-1053.

Auer, N.A., editor. 1982. Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. Great Lakes Fishery Comm., Ann Arbor, MI. 48105. Spec. Pub. 82-3:744 pp.

Becker, G.C. 1983. Fishes of Wisconsin. Univ. of Wisconsin Press. 1052 pp.

Beltz, J.R., J.W. Johnson, D.L. Cohen, and F.B. Pratt. 1974. An annotated bibliography of the effects of temperature on fish, with special reference to the freshwater and anadromous species of New England. Mass. Agr. Exp. Sta., Bull. No. 605, Univ. Mass. 97 pp.

Borgeson, D. 1983. Food habits of selected piscivorous fish in the St. Marys River. Mich. State Univ., Dept. of Fish. and Wildl., unpublished manuscript.

Brungs, W.A. 1977. Effects of reduced dissolved oxygen concentrations on warmwater fish. U.S. Environ. Prot. Agency, Env. Res. Lab., Duluth, Minnesota. 14 pp.

Cordone, A.J. and D. Kelly. 1961. The influence of organic sediment on the aquatic life of streams. Calif. Fish and Game 47:189-228.

Ellis, M.M. 1937. Detection and measurement of stream pollution. U.S. Dept. Comm. Bur. Fish. Bull. 22(48):365-437.

Emery, L. 1981. Range extension of pink salmon in the lower Great Lakes. Fisheries. 6(2): 7-10.

Hilsenhoff, W.L. 1975. Aquatic Insects of Wisconsin: with generic keys and notes of biology, ecology, and distribution. Tech. Bull. No. 89, Dept. Nat. Res., Madison, Wis. 53pp.

Holsinger, J.R. 1976. The freshwater amphipod crustaceans (Gammaridae) of North America. U.S. Envir. Prot. Agency. Envir. Monitor. and Support Lab. Pub. No. 18050 ELD04/72. 89 pp.

Hunt, G.S. 1962. Water pollution and the ecology of some aquatic invertebrates in the lower Detroit River. Proc. 5th Conf. Great Lakes Res., Univ. Mich., Great lakes Res. Div. Pub. No. 9. pp. 29-50.

Joyce, R. 1983. Food habits of the walleye (Stizostedion vitreum), sauger (Stizostedion canadense) and yellow perch (Perca flavescens) in the St. Marys River. Mich. State Univ., Dept. Fish. and Wildl., unpublished manuscript.

Jude, D.J., G.R. Heufelder, N.A. Auer, H.T. Tin, S.A. Klinger, P.J. Schneeberger, C.P. Madenjian, T.L. Rutecki, G.G. Godun. 1980. Adult, juvenile and larval fish populations in the vicinity of the J.H. Campbell Power Plant, eastern Lake Michigan, 1979. Spec. Rep. No. 79, Great Lakes Research Div., Univ. of Michigan, Ann-Arbor, MI. 607 pp.

Lam, C.N. H. and J. C. Roff. 1977. A method for separating alewife, Alsoa pseudoharengus, from gizzard shad, Dorosoma cepedianum, larvae. J. Great Lakes Res. 3(3-4): 313-316.

Liston, C.R. , W.G. Duffy, D.E. Ashton, C.D. McNabb and F.E. Koehler. 1980. Environmental baseline and evaluation of the St. Marys River dredging. Mich. State Univ., Dept. Fish. Wildl. Rep. to U.S. Fish Wildl. Serv., FWS/OBS-80/62. 295 pp.

___________ , W.G. Duffy, D.E. Ashton, T. Batterson, and C.D. McNabb. 1981. Supplementary environmental baseline studies and evaluation of the St. Marys River, 1980. Mich. State Univ., Dept. Fish. Wildl. Rep. to U.S. Fish. Wildl. Serv., FWS/OBS-80/62.1. 167 pp.

___________ , C.D. McNabb, W.G. Duffy, D.E. Ashton, R.L. Ligman, F.E. Koehler, J. Bohr, G. W. Fleisher, J. Schuette, and R. Yanusz. 1983. Environmental baseline studies of the St. Marys River near Neebish Island, Michigan, prior to proposed extension of the navigation season, 1981. Mich. State Univ., Dept. Fish. Wildl. Rep. to U.S. Fish. Wildl. Serv., FWS/OBS-80/62.2. 316 pp.

_____________ , C.D. McNabb, D. Brazo, J. Bohr, J. Craig, W. Duffy, G. Fleischer, G. Knoecklein, F. Koehler, R. Ligman, R. O'Neal, M. Siami, and P. Roettger. 1985. Limnological and fisheries studies of the St. Marys River, Michigan, in relation to proposed extension of the navigation season, 1982 and 1983. Mich. State Univ., Dept. Fish. Wildl. Rep. to U.S. Fish. Wildl. Serv., FWS/OBS-80/62.3. 764 pp. plus appendices..

Merritt, R.W. and K.W. Cummins (eds.). 1978. An introduction to the aquatic insects of North America. Kendall/Hunt, Dubuque, Iowa. 441 pp.

Morton, J. W. 1977. Ecological effects of dredging and dredge spoil disposal: a literature review. U.S. Fish Wildl. Tech. Paper 94. 33 pp.

Peddicord, R.K. and V.A. McFarland. 1978. Effects of suspended dredged material on aquatic animals. Dredged material Res. Prog., Tech. Rep. D-78-29. USACE. 115 pp.

Pennak, R.W. 1978. Freshwater invertebrates of the United States, 2nd ed. John Wiley and Sons, New York. 803 pp.

Poe, T.P., T. A. Edsall, and J.K. Hiltunen. 1979. Effects of ship induced waves in an ice environment in the St. Marys River ecosystem. Rep. Prog. No. 5100, Great Lakes Basin Comm., 24 pp. and appendices.

Sargent, M. 1982. Walleye (Stizostedion vitreum) food habits in the St. Marys River system. Mich. State Univ., Dept. Fish. Wildl., unpublished manuscript.

Schubel, J.R. and J.C.S. Wang. 1973. The effects of suspended sediment on the hatching success of Perca flavescens (yellow perch), Morone americana (white perch), Morone saxatilus (stripped bass), and Alosa pseudoharengus (alewife) eggs. Special report 30. Chesapeake Bay Institute, Johns Hopkins Univ. , Baltimore, MD.

Shark, J.A., J.M. O'Conner, D.A. Neumann, R.D. Prince, and K.V. Wood. 1974. Effects of suspended and deposited sediments on estuarine organisims, phase II. Final Report U.S. Army Corps of Eng. Cont. No. DACW 72-71-C-003. Univ. Md., Nat. Res. Inst., Ref. No. 74-20. 410 pp. In E.M. Stern and W.P. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Lit. Rev. Dredged Material Res. Prog. Tech. Rept. D-78-21. 118 pp.

Stern, E. M. and W. B. Stickle. 1978. Effects of turbidity and suspended material in aquatic environments. Lit. Rev. Dredged Material Res. Prog. Tech. Rept. D-78-21. 118 pp.

Swenson, W. A. and M.L. Matson. 1976. Influence of turbidity on survival, growth and distribution of larval lake herring (Coregonus artedii), Trans. Amer. Fish. Soc. 4:541-545.

Tarplee, W.H., W.T. Bryson, and R.G. Sherfinski. 1979. Portable push-net apparatus for sampling ichthyoplankton. Prog. Fish-Cult. 41(4):213-215.

Twenhofel, W.H. 1950. Principles of sedimentation. 2nd ed. McGraw-Hill, NY. 673 pp.

U.S. Army Engineer School. 1977. Soils Engineering, Vol I. (student Pamphlet). Ft. Belvoir, VA. pp. 93-115.

U.S. Environmental Protection Agency. 1977. Guidelines for the pollution classification of Great Lakes harbor sediments. U.S.EPA, Region V, Chicago, Ill. 7 pp

U.S. Fish and Wildlife Service. 1970. Effects on fish resources of dredging and spoil disposal in San Francisco and San Pablo Bays, California, Unnumbered Spec. Rept., Nov. 1970. Washington, D.C.

Whalen, M. 1980. Food habits, age, and growth of yellow perch (Perca flavescens) and walleye (Stizostedion vitreum) in the St. Marys River. Unpublished manuscript, Dep. Fish. and Wildl., Mich. State Univ. 23 pp.

Wiggens, G.B. 1977. Larvae of the North American caddisfly genera (Trichoptera). Univ. of Toronto Press, Toronto. 401 pp.

Wilber, C.G. 1971. Turbidity, pp. 1157-1194. In O.Kinne (ed.) Marine ecology: a comprehensive integrated treatise on life in oceans and coastal waters, Vol. 1, Part 2. Wiley-Interscience, Wiley:New York.

Appendix A. Physical and chemical data taken in Munuscong Bay during various fish sampling programs in 1984.

Appendix A.1. Physical and chemcial data taken while sampling larval fish with 1.0 m tow nets in Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
C2	4/23	2340	3.5	13.0	-
	5/8	2350	-	-	2.0
	5/23	0015	8.0	-	2.0
	6/5	2345	10.0	11.8	3.0
	6/20	0100	10.0	12.2	3.3
	7/4	0110	13.5	11.4	2.5
	7/24	0015	17.0	9.5	6.0
	8/7	0025	18.0	9.0	4.0
	8/20	0000	20.0	9.3	4.0
C3	4/23	2300	5.0	12.4	23.0
	5/8	2340	-	-	2.8
	5/23	2330	8.5	-	4.5
	6/5	0030	10.0	11.8	5.0
	6/20	0005	11.0	11.6	2.7
	7/4	0045	14.0	10.5	4.0
	7/24	2350	17.5	9.5	6.0
	8/6	2345	19.0	9.1	7.0
	8/20	2300	20.0	9.4	7.0
C7	5/8	2310	-	-	2.3
	5/22	2300	8.0	-	2.2
	6/5	0100	9.5	11.8	5.0
	6/20	2330	11.0	10.2	2.0
	7/3	2315	14.5	10.2	4.0
	7/24	2320	18.0	9.0	6.0
	8/6	2315	19.0	10.2	4.0
	8/21	2235	-	-	-

---

[1] Sampling stations are shown in Figure 6.

Appendix A.2. Physical and chemical data taken while sampling larval fish with 0.5 m push nets in Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
S1	4/23	2015	7.5	11.2	45.0
	5/8	2130	10.5	10.5	68.0
	5/22	2135	16.0	8.7	24.0
	6/4	2145	17.5	8.2	31.0
	6/19	2156	16.0	8.1	24.0
	7/3	2148	19.5	7.4	34.0
	7/23	2150	-	-	-
	8/6	2157	23.0	7.8	14.0
	8/20	2122	21.0	9.2	17.0
S2	4/23	2350	-	-	3.0
	5/9	0015	9.0	10.4	-
	5/23	0010	8.0	12.8	2.1
	6/5	0045	14.5	9.8	15.0
	6/20	0042	9.5	11.4	1.7
	7/4	0020	15.0	8.0	7.0
	7/23	2150	-	-	-
	8/7	0022	17.0	10.5	3.5
	8/20	2331	18.0	8.7	6.0
S3	4/23	2325	3.5	-	8.0
	5/8	2350	5.0	12.5	2.7
	5/22	2345	8.0	12.9	3.2
	6/5	0030	9.5	11.4	6.0
	6/20	0022	9.0	11.2	2.0
	7/3	2354	14.0	9.0	5.0
	7/23	2355	-	-	-
	8/6	2345	18.0	10.0	3.5
	8/20	2308	19.5	-	6.0
S4	4/23	2250	4.0	-	5.0
	5/8	2330	5.0	12.4	2.2
	5/22	2320	10.0	12.1	3.6
	6/5	0000	11.0	10.8	3.0
	6/19	2355	10.0	11.0	2.5
	7/4	2340	15.0	9.0	4.5
	7/23	2320	-	-	-
	8/6	2314	20.0	10.0	6.0
	8/20	2250	19.0	9.2	4.0

Appendix A.2. (Continued)

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
S5	4/23	2115	6.0	12.0	12.0
	5/8	2255	7.0	11.7	5.5
	5/22	2115	13.5	10.9	13.0
	6/5	2230	13.0	10.5	22.0
	6/20	2237	15.0	9.8	12.0
	7/3	2230	16.0	10.0	7.0
	7/23	2230	-	-	-
	8/6	2229	21.5	9.2	23.5
	8/20	2205	20.0	9.6	5.0
S6	5/8	2200	8.0	11.2	8.7
	5/22	2210	14.5	10.5	16.5
	6/5	2215	15.0	9.3	34.0
	6/19	2216	15.0	9.5	12.0
	7/3	2214	17.5	9.2	14.0
	7/23	2220	20.0	8.5	86.0
	8/6	2214	22.0	8.5	35.0
	8/20	2149	20.5	9.0	24.0
S7	4/23	2210	7.0	11.7	27.0
	5/8	2305	6.0	12.6	2.2
	5/22	2305	12.0	11.7	6.5
	6/5	2330	11.0	11.0	3.0
	6/19	2335	12.0	10.7	4.0
	7/3	2320	15.1	10.2	3.5
	7/23	2300	-	-	-
	8/6	2300	20.0	10.5	11.0
	8/20	2235	19.2	9.8	10.5
S8	4/23	2150	7.0	11.0	44.0
	5/8	2245	8.0	11.7	5.9
	5/22	2245	13.0	11.4	9.5
	6/5	2300	15.0	10.2	16.0
	6/19	2319	16.0	9.2	27.0
	7/3	2300	16.2	10.0	6.0
	7/23	2245	19.0	9.0	43.0
	8/6	2245	20.0	9.8	13.0
	8/20	2221	20.0	9.2	14.0

---

[1] Sampling stations are shown in Figure 6.

Appendix A.3. Physical and chemical data taken while sampling larval fish with pull nets in shallow water, Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
L1	4/23	2010	7.0	9.4	64.0
	5/8	2115	-	-	35.0
	5/22	2205	16.0	-	23.0
	6/4	2215	18.0	7.3	23.0
	6/20	2200	18.5	9.5	10.1
	7/3	2200	20.0	5.0	14.0
	7/23	2200	23.0	6.3	17.0
	8/6	2200	24.0	5.5	12.0
	8/20	2130	20.0	7.0	19.0
L2	4/23	0015	3.5	12.4	45.0
	5/8	0005	-	-	52.0
	5/23	0115	8.0	-	21.0
	6/5	0130	16.0	7.8	20.0
	6/20	2250	20.0	8.6	6.3
	7/4	0020	18.0	10.0	13.5
	7/24	0045	17.0	8.5	4.0
	8/7	0045	19.0	7.5	-
	8/20	2340	20.0	8.6	12.5
L8	4/23	2145	7.5	10.0	54.0
	5/8	2330	-	-	2.3
	5/22	2235	16.5	-	13.0
	6/4	2315	18.0	9.9	14.0
	6/20	0040	10.0	11.0	2.0
	7/3	2240	17.5	10.0	9.0
	7/24	0030	23.0	7.4	6.0
	8/6	2230	24.0	5.5	6.5
	8/20	2200	24.0	7.4	4.0

[1] Sampling stations are shown in Figure 6.

Appendix A.4. Physical and chemical data taken during fish sampling with bottom trawls, Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
1	5/30	2200	12.0	10.0	11.0
	7/6		-	-	-
	7/26	2200	21.0	10.2	20.0
	8/27		-	-	-
2	5/31	0130	8.0	11.5	4.5
	7/6		-	-	-
	7/26		16.2	10.0	4.0
	8/27		-	-	-
2A	5/31	0100	8.0	11.5	3.2
	7/6		-	-	-
	7/27	0000	16.0	12.1	4.0
	8/27		-	-	-
3	5/31	0040	8.0	11.7	6.2
	7/6		-	-	-
	7/27	2330	17.0	12.2	5.0
	8/27				
4	5/30	2245	8.0	11.8	2.9
	7/6		-	-	-
	7/27	2330	17.0	12.2	5.0
	8/27		-	-	-
7	5/31	0015	9.0	11.6	3.0
	7/6		-	-	-
	7/27		18.0	10.0	5.0
	8/27				
7A	5/30	2345	9.0	10.8	2.5
	7/6		-	-	-
	7/27		18.0	10.2	7.0
	8/27				
8	5/30	2315	12.0	10.0	23.0
	7/6		-	-	-
	7/27		20.0	10.0	4.0
	8/27		-	-	-

---

[1] Stations are shown in Figure 7.

Appendix A.5. Physical and chemical data taken during fish sampling with small mesh trap nets in Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C °)	Dissolved Oxygen (ppm)	Turbidity (NTU)
2S	4/24		4.5	13.6	5.0
1S	8/29		18.5	7.0	11.0
1aS	8/16		22.0	6.3	54.0
	8/29		22.0	6.9	-
1bS	7/18		20.0	7.5	82.0
	7/30		22.0	7.6	46.0
	8/13		22.0	5.7	69.0
2S	7/18		20.0	8.4	64.0
	7/30		21.5	7.8	18.0
	8/13		22.0	5.4	27.0
4S	7/9		no data available		
5S	8/16		22.0	7.7	34.0
	8/29		20.5	8.0	14.0
6S	7/9		15.5	10.2	3.0
	7/18		19.0	8.2	20.0
	8/13		21.0	7.3	54.0
8S	8/16		21.5	7.7	38.0
	8/29		20.0	7.7	13.0

---

[1] Stations are shown in Figure 8.

Appendix A.6. Physical and chemical data taken during fish sampling with large mesh trap nets, Munuscong Bay, 1984.

Station[1]	Date	Time	Water Temperature (C°)	Dissolved Oxygen (ppm)	Turbidity (NTU)
2L	4/24		4.5	13.6	5.0
	5/14		6.0	13.2	-
	6/26		-	-	-
	7/11		-	-	-
	8/6		19.0	10.0	3.7
	8/7		18.0	10.0	3.0
	8/27		20.5	7.4	13.0
	9/18		12.5	8.8	5.0
	9/19		14.0	10.2	3.0
3L	4/24		3.0	13.5	3.0
	5/14		5.5	13.1	-
	6/26		-	-	-
	7/11		-	-	-
	8/7		18.0	9.8	4.5
	8/8		19.0	10.2	4.5
	8/27		19.0	9.2	5.0
	9/18		13.0	9.0	4.0
	9/19		14.0	10.1	3.0
5L	4/18		5.0	12.0	50.0
	5/8		8.0	11.8	10.0
	6/12		-	-	-
	7/11		-	-	-
	8/7		21.3	8.8	19.0
	8/27		19.0	8.9	4.0
	9/17		13.0	10.2	7.0
	9/18		11.0	-	6.0
8L	4/18		4.0	13.7	64.0
	5/16		5.0	13.0	6.0
	6/13		-	-	-
	7/10		-	-	-
	8/6		20.0	9.8	6.5
	8/7		22.0	9.0	10.0
	8/27		19.0	9.2	6.0
	9/17		13.0	10.2	5.0
	9/18		-	-	4.0

---

1 Stations are shown in Figure 8.

Appendix B. Collection records for each benthic macroinvertebrate sample including date, gear type (PONAR or Ekman dredge), station/site, density (no./m^2) and descriptive statistics for each taxa.

BLANK PAGE

BLANK PAGE

BLANK PAGE

GEAR : PONAR

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
			DENSITIES (# / SQ. M)								
05/02/84	P 1	1 CAENIS	0	0	21	0	0	0	7.0	12.1	7.0
		1 HEXAGENIA	546	147	273	0	0	0	322.0	204.0	117.8
		2 OECETIS	0	105	0	0	0	0	35.0	60.6	35.0
		2 PHYLOCENTR	147	42	126	0	0	0	105.0	55.6	32.1
		4 CERATOPOGO	0	0	21	0	0	0	7.0	12.1	7.0
		4 CHIRONOMID	4557	4935	3759	0	0	0	4417.0	600.4	346.6
		4 PUPAE	42	0	21	0	0	0	21.0	21.0	12.1
		8 CORIXIDAE	0	0	21	0	0	0	7.0	12.1	7.0
		15 HYDRACARIN	42	0	21	0	0	0	21.0	21.0	12.1
		16 CAMPELOMA	63	21	63	0	0	0	49.0	24.2	14.0
		16 GYRAULUS	0	0	21	0	0	0	7.0	12.1	7.0
		16 LYMNAEA	0	21	0	0	0	0	7.0	12.1	7.0
		17 SPHAERIUM	21	105	210	0	0	0	112.0	94.7	54.7
		19 OLIGOCHAET	5607	7686	6909	0	0	0	6734.0	1050.5	606.5
		20 TURBELLARI	21	0	0	0	0	0	7.0	12.1	7.0
		21 NEMATODA	4410	1050	1050	0	0	0	2170.0	1939.9	1120.0
		23 OSTRACODA	840	9450	2310	0	0	0	4200.0	4605.7	2659.1
		24 HIRUDINEA	21	21	0	0	0	0	14.0	12.1	7.0

Grand Sum = 54726 Mean = 18242.0 Std.Dev. = 4685.1 Std.Err = 2705.0

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 2	1 CAENIS	0	210	0	0	0	0	70.0	121.2	70.0
		1 HEXAGENIA	63	0	21	0	0	0	28.0	32.1	18.5
		2 CERACLEA	0	21	0	0	0	0	7.0	12.1	7.0
		2 MYSTACIDES	63	84	21	0	0	0	56.0	32.1	18.5
		2 OECETIS	21	0	0	0	0	0	7.0	12.1	7.0
		2 POLYCENTRO	105	210	84	0	0	0	133.0	67.5	39.0
		2 TRIANODES	0	21	21	0	0	0	14.0	12.1	7.0
		4 CERATOPOGO	147	105	126	0	0	0	126.0	21.0	12.1
		4 CHIRONOMID	18942	12999	9114	0	0	0	13685.0	4949.8	2857.8
		4 PUPAE	252	168	105	0	0	0	175.0	73.7	42.6
		12 ASELLUS	210	189	42	0	0	0	147.0	91.5	52.8
		12 LIRCEUS	672	168	273	0	0	0	371.0	265.9	153.5
		13 HYALELLA A	2604	1134	672	0	0	0	1470.0	1008.9	582.5
		15 HYDRACARIN	63	84	21	0	0	0	56.0	32.1	18.5
		16 AMNICOLA	63	0	84	0	0	0	49.0	43.7	25.2
		16 GYRAULUS	21	0	42	0	0	0	21.0	21.0	12.1
		16 PHYSA	21	0	0	0	0	0	7.0	12.1	7.0
		16 VALVATA SI	0	42	0	0	0	0	14.0	24.2	14.0
		17 PISIDIUM	0	21	21	0	0	0	14.0	12.1	7.0
		19 OLIGOCHAET	3276	1974	420	0	0	0	1890.0	1429.9	825.5
		20 TURBELLARI	0	273	21	0	0	0	98.0	151.9	87.7
		21 NEMATODA	4431	2184	1050	0	0	0	2555.0	1720.8	993.5
		23 OSTRACODA	5040	3360	630	0	0	0	3010.0	2225.7	1285.0

Grand Sum = 72009 Mean = 24003.0 Std.Dev. = 11631.4 Std.Err = 6715.4

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 2A	1 CAENIS	0	231	0	0	0	0	77.0	133.4	77.0
		1 HEXAGENIA	472	336	315	0	0	0	374.3	85.2	49.2
		2 MYSTACIDES	26	0	21	0	0	0	15.7	13.8	8.0
		2 PHYLOCENTR	26	0	0	0	0	0	8.7	15.0	8.7
		2 POLYCENTRO	0	0	21	0	0	0	7.0	12.1	7.0
		2 TRIANODES	26	0	0	0	0	0	8.7	15.0	8.7
		4 CERATOPOGO	210	0	147	0	0	0	119.0	107.8	62.2
		4 CHIRONOMID	15330	12453	20139	0	0	0	15974.0	3883.3	2242.0
		4 PUPAE	289	42	168	0	0	0	166.3	123.5	71.3
		12 ASELLUS	236	126	105	0	0	0	155.7	70.4	40.6
		12 LIRCEUS	0	84	0	0	0	0	28.0	48.5	28.0
		13 HYALELLA A	52	84	168	0	0	0	101.3	59.9	34.6
		15 HYDRACARIN	52	0	84	0	0	0	45.3	42.4	24.5
		16 HELISOMA	26	0	0	0	0	0	8.7	15.0	8.7
		19 OLIGOCHAET	630	1176	378	0	0	0	728.0	407.9	235.5
		20 TURBELLARI	52	0	336	0	0	0	129.3	180.9	104.4
		21 NEMATODA	4042	1890	3024	0	0	0	2985.3	1076.5	621.5
		23 OSTRACODA	2625	4410	3360	0	0	0	3465.0	897.1	518.0

Grand Sum = 73192 Mean = 24397.3 Std.Dev. = 3726.3 Std.Err = 2151.4

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 3	1 HEXAGENIA	231	1344	273	0	0	0	616.0	630.8	364.2
		2 POLYCENTRO	210	0	0	0	0	0	70.0	121.2	70.0
		4 CERATOPOGO	21	21	21	0	0	0	21.0	0.0	0.0
		4 CHIRONOMID	7224	6300	6321	0	0	0	6615.0	527.5	304.6
		4 PUPAE	105	84	84	0	0	0	91.0	12.1	7.0
		13 HYALELLA A	252	42	0	0	0	0	98.0	135.0	77.9
		16 AMNICOLA	0	42	0	0	0	0	14.0	24.2	14.0
		16 LYMNAEIDAE	0	21	0	0	0	0	7.0	12.1	7.0
		16 VALVATA TR	0	21	0	0	0	0	7.0	12.1	7.0
		19 OLIGOCHAET	1554	630	231	0	0	0	805.0	678.6	391.8
		21 NEMATODA	1260	2331	2100	0	0	0	1897.0	563.6	325.4
		23 OSTRACODA	3570	2100	2100	0	0	0	2590.0	848.7	490.0
		24 HIRUDINEA	0	21	0	0	0	0	7.0	12.1	7.0

Grand Sum = 38514 Mean = 12838.0 Std.Dev. = 1651.7 Std.Err = 953.6

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 4	1 CAENIS	0	0	21	0	0	0	7.0	12.1	7.0
		1 EPHEMERA	63	21	84	0	0	0	56.0	32.1	18.5
		1 HEXAGENIA	84	42	0	0	0	0	42.0	42.0	24.2
		2 CERACLEA	0	21	0	0	0	0	7.0	12.1	7.0
		2 MYSTACIDES	0	0	42	0	0	0	14.0	24.2	14.0
		2 POLYCENTRO	42	21	42	0	0	0	35.0	12.1	7.0
		2 TRIANODES	0	0	21	0	0	0	7.0	12.1	7.0
		4 CHIRONOMID	4683	3591	2520	0	0	0	3598.0	1081.5	624.4
		4 PUPAE	273	315	252	0	0	0	280.0	32.1	18.5
		7 COLLEMBOLA	0	0	210	0	0	0	70.0	121.2	70.0
		12 ASELLUS	21	21	0	0	0	0	14.0	12.1	7.0
		12 LIRCEUS	189	105	63	0	0	0	119.0	64.2	37.0
		13 GAMMARUS	42	63	0	0	0	0	35.0	32.1	18.5
		13 HYALELLA A	1092	987	546	0	0	0	875.0	289.7	167.3
		14 ORCONECTES	21	21	0	0	0	0	14.0	12.1	7.0
		15 HYDRACARIN	63	0	21	0	0	0	28.0	32.1	18.5
		16 AMNICOLA	252	21	126	0	0	0	133.0	115.7	66.8
		16 GYRAULUS	84	42	42	0	0	0	56.0	24.2	14.0
		16 PHYSA	21	42	21	0	0	0	28.0	12.1	7.0
		16 VALVATA SI	42	0	0	0	0	0	14.0	24.2	14.0
		16 VALVATA TR	0	0	21	0	0	0	7.0	12.1	7.0
		17 PISIDIUM	84	0	0	0	0	0	28.0	48.5	28.0
		17 SPHAERIUM	63	21	21	0	0	0	35.0	24.2	14.0
		19 OLIGOCHAET	1470	1344	1218	0	0	0	1344.0	126.0	72.7
		20 TURBELLARI	63	0	0	0	0	0	21.0	36.4	21.0
		21 NEMATODA	1701	2520	2982	0	0	0	2401.0	648.7	374.5
		23 OSTRACODA	1260	1050	1680	0	0	0	1330.0	320.8	185.2

Grand Sum = 31794 Mean = 10598.0 Std.Dev. = 893.0 Std.Err = 515.6

B5

GEAR : PONAR

			DENSITIES (# / SQ. M)								
DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 5	1 CAENIS	0	252	420	0	0	0	224.0	211.4	122.0
		1 EPHEMERA	63	21	21	0	0	0	35.0	24.2	14.0
		1 HEXAGENIA	84	42	63	0	0	0	63.0	21.0	12.1
		2 CERACLEA	42	0	0	0	0	0	14.0	24.2	14.0
		2 MYSTACIDES	21	0	42	0	0	0	21.0	21.0	12.1
		2 OECETIS	0	42	0	0	0	0	14.0	24.2	14.0
		2 POLYCENTRO	0	0	42	0	0	0	14.0	24.2	14.0
		2 TRIANODES	0	0	21	0	0	0	7.0	12.1	7.0
		4 CERATOPOGO	0	21	0	0	0	0	7.0	12.1	7.0
		4 CHIRONOMID	6426	8904	3822	0	0	0	6384.0	2541.3	1467.2
		4 PUPAE	210	210	0	0	0	0	140.0	121.2	70.0
		7 COLLEMBOLA	210	0	0	0	0	0	70.0	121.2	70.0
		8 CORIXIDAE	0	0	21	0	0	0	7.0	12.1	7.0
		12 ASELLUS	0	0	21	0	0	0	7.0	12.1	7.0
		12 LIRCEUS	0	21	0	0	0	0	7.0	12.1	7.0
		13 GAMMARUS	0	0	84	0	0	0	28.0	48.5	28.0
		13 HYALELLA A	1386	2310	1008	0	0	0	1568.0	669.8	386.7
		15 HYDRACARIN	0	21	21	0	0	0	14.0	12.1	7.0
		16 AMNICOLA	0	42	189	0	0	0	77.0	99.2	57.3
		16 CAMPELOMA	21	0	42	0	0	0	21.0	21.0	12.1
		16 GONIOBASIS	0	21	0	0	0	0	7.0	12.1	7.0
		16 GYRAULUS	0	63	147	0	0	0	70.0	73.7	42.6
		16 LYMNAEA	0	42	21	0	0	0	21.0	21.0	12.1
		16 PHYSA	0	0	42	0	0	0	14.0	24.2	14.0
		16 VALVATA SI	21	189	0	0	0	0	70.0	103.6	59.8
		16 VALVATA TR	0	21	0	0	0	0	7.0	12.1	7.0
		17 PISIDIUM	0	0	42	0	0	0	14.0	24.2	14.0
		17 SPHAERIUM	42	0	63	0	0	0	35.0	32.1	18.5
		19 OLIGOCHAET	2415	2310	777	0	0	0	1834.0	916.9	529.4
		20 TURBELLARI	0	0	105	0	0	0	35.0	60.6	35.0
		21 NEMATODA	2373	2961	630	0	0	0	1988.0	1212.3	699.9
		23 OSTRACODA	1050	2520	1050	0	0	0	1540.0	848.7	490.0

Grand Sum = 43071 Mean = 14357.0 Std.Dev. = 5659.5 Std.Err = 3267.5

11L

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 7	1 HEXAGENIA	0	21	0	0	0	0	7.0	12.1	7.0
		2 MOLANNA	0	0	21	0	0	0	7.0	12.1	7.0
		4 CERATOPOGO	0	42	0	0	0	0	14.0	24.2	14.0
		4 CHIRONOMID	2415	1470	672	0	0	0	1519.0	872.5	503.8
		15 HYDRACARIN	0	0	21	0	0	0	7.0	12.1	7.0
		16 AMNICOLA	42	0	0	0	0	0	14.0	24.2	14.0
		16 LYMNAEIDAE	21	42	0	0	0	0	21.0	21.0	12.1
		17 PISIDIUM	21	42	63	0	0	0	42.0	21.0	12.1
		19 OLIGOCHAET	462	0	168	0	0	0	210.0	233.8	135.0
		21 NEMATODA	1911	840	0	0	0	0	917.0	957.8	553.0
		24 HIRUDINEA	0	21	0	0	0	0	7.0	12.1	7.0

Grand Sum = 8295 Mean = 2765.0 Std.Dev. = 1979.2 Std.Err = 1142.7

GEAR : PONAR

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 7A	1 EPHEMERA	21	0	0	0	0	0	7.0	12.1	7.0
		1 HEXAGENIA	231	231	105	0	0	0	189.0	72.7	42.0
		4 CHIRONOMID	2856	1827	2919	0	0	0	2534.0	613.1	354.0
		4 PUPAE	0	210	0	0	0	0	70.0	121.2	70.0
		8 CORIXIDAE	0	21	0	0	0	0	7.0	12.1	7.0
		17 PISIDIUM	147	42	0	0	0	0	63.0	75.7	43.7
		17 SPHAERIUM	21	0	0	0	0	0	7.0	12.1	7.0
		19 OLIGOCHAET	4137	3507	3864	0	0	0	3836.0	315.9	182.4
		21 NEMATODA	2331	1050	1260	0	0	0	1547.0	687.0	396.7
		23 OSTRACODA	420	210	840	0	0	0	490.0	320.8	185.2

Grand Sum = 26250 Mean = 8750.0 Std.Dev. = 1546.8 Std.Err = 893.0

```
GEAR : PONAR


                                                    DENSITIES  ( # / SQ. M )
 DATE       STATION         TAXON          REP1     REP2     REP3     REP4     REP5     REP6        MEAN       Std.Dev.      Std.Err.


05/02/84     P 8A        1 EPHEMERA           0        0       21        0        0        0         7.0          12.1           7.0
                         1 HEXAGENIA          0       21      147        0        0        0        56.0          79.5          45.9
                         2 CERACLEA           0       21        0        0        0        0         7.0          12.1           7.0
                         2 MOLANNA            0       63        0        0        0        0        21.0          36.4          21.0
                         2 MYSTACIDES        21       42       21        0        0        0        28.0          12.1           7.0
                         2 OXYETHIRA          0        0       21        0        0        0         7.0          12.1           7.0
                         2 POLYCENTRO         0       21       21        0        0        0        14.0          12.1           7.0
                         2 TRIANODES          0       21        0        0        0        0         7.0          12.1           7.0
                         4 CERATOPOGO        21       21       21        0        0        0        21.0           0.0           0.0
                         4 CHIRONOMID      4557     3948     4851        0        0        0      4452.0         460.6         265.9
                         4 PUPAE             84        0        0        0        0        0        28.0          48.5          28.0
                        12 LIRCEUS          189       84       42        0        0        0       105.0          75.7          43.7
                        13 HYALELLA A      1281     1281     1029        0        0        0      1197.0         145.5          84.0
                        15 HYDRACARIN       126       21       63        0        0        0        70.0          52.8          30.5
                        16 AMNICOLA          21       21      126        0        0        0        56.0          60.6          35.0
                        16 GYRAULUS         126       21        0        0        0        0        49.0          67.5          39.0
                        16 LYMNAEIDAE        21       21       21        0        0        0        21.0           0.0           0.0
                        16 PHYSA             63       21        0        0        0        0        28.0          32.1          18.5
                        16 VALVATA SI       126       21        0        0        0        0        49.0          67.5          39.0
                        16 VALVATA TR        21       21       21        0        0        0        21.0           0.0           0.0
                        17 ANODONTOID       441        0        0        0        0        0       147.0         254.6         147.0
                        17 PISIDIUM          84      126       63        0        0        0        91.0          32.1          18.5
                        17 SPHAERIUM         42       42       42        0        0        0        42.0           0.0           0.0
                        19 OLIGOCHAET      1155      798      714        0        0        0       889.0         234.2         135.2
                        20 TURBELLARI        63      105       42        0        0        0        70.0          32.1          18.5
                        21 NEMATODA        4221     2940     4410        0        0        0      3857.0         799.7         461.7
                        23 OSTRACODA        840      420      210        0        0        0       490.0         320.8         185.2

              Grand Sum =    35490     Mean =  11830.0     Std.Dev. =    1701.7     Std.Err =     982.5
```

GEAR : PONAR

DATE	STATION	TAXON	DENSITIES (# / SQ. M) REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	P 8	1 CAENIS	21	231	0	0	0	0	84.0	127.7	73.7
		1 EPHEMERA	21	21	105	0	0	0	49.0	48.5	28.0
		1 HEXAGENIA	483	504	0	0	0	0	329.0	285.1	164.6
		2 MYSTACIDES	0	0	21	0	0	0	7.0	12.1	7.0
		4 CERATOPOGO	0	0	42	0	0	0	14.0	24.2	14.0
		4 CHIRONOMID	1785	4557	1596	0	0	0	2646.0	1657.7	957.1
		4 PUPAE	84	378	0	0	0	0	154.0	198.5	114.6
		8 CORIXIDAE	0	21	0	0	0	0	7.0	12.1	7.0
		13 HYALELLA A	21	0	378	0	0	0	133.0	212.4	122.6
		15 HYDRACARIN	0	0	42	0	0	0	14.0	24.2	14.0
		16 CAMPELOMA	0	21	42	0	0	0	21.0	21.0	12.1
		16 GYRAULUS	0	0	42	0	0	0	14.0	24.2	14.0
		16 UNKNOWN	0	0	42	0	0	0	14.0	24.2	14.0
		16 VALVATA SI	0	42	0	0	0	0	14.0	24.2	14.0
		17 SPHAERIUM	0	0	21	0	0	0	7.0	12.1	7.0
		19 OLIGOCHAET	882	9072	798	0	0	0	3584.0	4752.9	2744.1
		20 TURBELLARI	0	0	21	0	0	0	7.0	12.1	7.0
		21 NEMATODA	630	2100	840	0	0	0	1190.0	795.0	459.0
		23 OSTRACODA	630	2730	2100	0	0	0	1820.0	1077.6	622.2

Grand Sum = 30324 Mean = 10108.0 Std.Dev. = 8322.4 Std.Err = 4804.9

GEAR : ECKMAN

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	E 1	1 CAENIS	0	0	43	0	86	0	21.5	36.0	14.7
		1 HEXAGENIA	43	43	43	86	1161	0	229.3	457.2	186.7
		2 MYSTACIDES	0	0	0	0	43	0	7.2	17.6	7.2
		2 PHYLOCENTR	43	0	172	86	43	129	78.8	63.3	25.8
		4 CERATOPOGO	43	0	43	86	0	0	28.7	35.1	14.3
		4 CHIRONOMID	8127	4429	15953	9116	12556	8213	9732.3	4001.5	1633.6
		4 PUPAE	0	0	86	0	172	0	43.0	72.0	29.4
		8 CORIXIDAE	344	0	86	0	0	43	78.8	134.4	54.9
		12 ASELLUS	0	86	0	0	0	0	14.3	35.1	14.3
		13 GAMMARUS	43	0	0	0	0	0	7.2	17.6	7.2
		13 HYALELLA A	0	0	0	0	215	0	35.8	87.8	35.8
		15 HYDRACARIN	129	0	129	0	43	0	50.2	63.3	25.8
		16 AMNICOLA	43	0	301	129	86	43	100.3	107.6	43.9
		16 CAMPELOMA	0	43	0	0	129	0	28.7	52.1	21.3
		16 GYRAULUS	0	43	129	43	0	86	50.2	50.3	20.5
		16 PHYSA	0	0	86	0	129	0	35.8	57.2	23.3
		16 VALVATA SI	0	129	0	0	0	172	50.2	78.9	32.2
		17 PISIDIUM	0	129	43	0	0	86	43.0	54.4	22.2
		17 SPHAERIUM	43	301	0	688	129	516	279.5	275.7	112.5
		19 OLIGOCHAET	1505	1978	4042	8772	4558	4859	4285.7	2594.1	1059.0
		20 TURBELLARI	0	43	688	43	0	0	129.0	274.7	112.1
		21 NEMATODA	1290	3870	17630	860	4730	6880	5876.7	6175.7	2521.2
		23 OSTRACODA	6020	3870	18490	2580	4730	1720	6235.0	6194.1	2528.7
		24 HIRUDINEA	0	0	43	43	0	0	14.3	22.2	9.1

Grand Sum = 164733 Mean = 27455.5 Std.Dev. = 15705.9 Std.Err = 6411.9

GEAR : ECKMAN

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	E 2	1 CAENIS	0	0	0	0	43	0	7.2	17.6	7.2
		1 EPHEMERA	0	43	0	0	43	0	14.3	22.2	9.1
		1 HEXAGENIA	0	129	0	43	43	0	35.8	50.3	20.5
		4 CERATOPOGO	0	43	0	0	0	0	7.2	17.6	7.2
		4 CHIRONOMID	1204	2107	688	344	1548	172	1010.5	745.7	304.4
		12 LIRCEUS	0	0	0	86	0	0	14.3	35.1	14.3
		13 HYALELLA A	344	0	0	0	86	0	71.7	137.8	56.2
		15 HYDRACARIN	129	43	0	43	43	0	43.0	47.1	19.2
		16 AMNICOLA	43	0	0	0	0	0	7.2	17.6	7.2
		19 OLIGOCHAET	1118	172	1548	344	3440	43	1110.8	1282.6	523.6
		20 TURBELLARI	0	0	0	43	0	0	7.2	17.6	7.2
		21 NEMATODA	1032	1720	430	129	688	301	716.7	584.3	238.6
		23 OSTRACODA	0	559	43	86	43	0	121.8	216.6	88.4

Grand Sum = 19006 Mean = 3167.7 Std.Dev. = 2123.5 Std.Err = 866.9

GEAR : ECKMAN

DENSITIES (# / SQ. M)

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
05/02/84	E 6	1 HEXAGENIA	129	43	215	172	86	0	107.5	80.4	32.8
		2 OECETIS	43	0	0	0	0	0	7.2	17.6	7.2
		2 POLYCENTRO	43	0	0	0	0	0	7.2	17.6	7.2
		4 CHIRONOMID	860	2494	19393	11739	2537	6966	7331.5	7117.7	2905.8
		4 PUPAE	172	258	258	0	86	516	215.0	178.3	72.8
		16 AMNICOLA	129	0	0	0	0	0	21.5	52.7	21.5
		16 CAMPELOMA	0	0	0	43	0	43	14.3	22.2	9.1
		16 VALVATA TR	301	0	0	0	0	0	50.2	122.9	50.2
		17 PISIDIUM	0	0	0	86	86	43	35.8	42.3	17.3
		17 SPHAERIUM	43	0	43	0	0	0	14.3	22.2	9.1
		19 OLIGOCHAET	3569	86	13330	17630	8686	38270	13595.2	13655.2	5574.7
		21 NEMATODA	258	129	3010	3870	3870	6450	2931.2	2414.5	985.7
		23 OSTRACODA	301	0	430	6450	1290	4300	2128.5	2640.0	1077.8

Grand Sum = 158756 Mean = 26459.3 Std.Dev. = 21290.2 Std.Err = 8691.7

BLANK PAGE

BLANK PAGE

BLANK PAGE

GEAR : ECKMAN

DATE	STATION	TAXON	REP1	REP2	REP3	REP4	REP5	REP6	MEAN	Std.Dev.	Std.Err.
			DENSITIES (# / SQ. M)								
05/02/84	E 8	1 CAENIS	86	387	301	258	903	129	344.0	295.4	120.6
		1 HEXAGENIA	0	0	0	43	0	0	7.2	17.6	7.2
		2 AGRYPNIA	43	0	43	0	0	43	21.5	23.6	9.6
		2 HYDROPTILA	0	0	0	0	43	0	7.2	17.6	7.2
		2 OECETIS	0	43	0	43	0	0	14.3	22.2	9.1
		2 POLYCENTRO	0	516	0	0	0	0	86.0	210.7	86.0
		3 DONACIA	0	0	0	43	0	0	7.2	17.6	7.2
		4 CERATOPOGO	43	43	0	0	43	43	28.7	22.2	9.1
		4 CHIRONOMID	3698	9116	7052	7396	6321	2752	6055.8	2395.7	978.1
		4 PUPAE	258	129	602	387	645	645	444.3	220.4	90.0
		5 ENALLAGMA	0	129	129	0	0	0	43.0	66.6	27.2
		10 PARAPONYX	0	0	43	43	0	0	14.3	22.2	9.1
		12 ASELLUS	129	1161	344	387	129	301	408.5	384.4	156.9
		12 LIRCEUS	1032	946	1677	645	903	774	996.2	360.2	147.0
		13 GAMMARUS	43	0	43	172	0	86	57.3	64.7	26.4
		13 HYALELLA A	172	473	172	129	258	172	229.3	126.6	51.7
		13 PONTOPORIA	0	86	0	0	0	0	14.3	35.1	14.3
		14 ORCONECTES	0	0	0	43	0	0	7.2	17.6	7.2
		15 HYDRACARIN	0	43	0	43	0	0	14.3	22.2	9.1
		16 AMNICOLA	0	0	0	0	0	43	7.2	17.6	7.2
		16 FERRISSIA	43	0	0	0	0	0	7.2	17.6	7.2
		16 GYRAULUS	215	258	86	0	0	86	107.5	107.9	44.1
		16 PHYSA	0	43	0	0	0	0	7.2	17.6	7.2
		16 VALVATA TR	0	0	43	0	0	0	7.2	17.6	7.2
		17 UNKNOWN	43	0	0	0	0	0	7.2	17.6	7.2
		19 OLIGOCHAET	1247	6149	645	430	301	3053	1970.8	2283.5	932.2
		20 TURBELLARI	86	0	0	86	0	0	28.7	44.4	18.1
		21 NEMATODA	2580	3870	2150	2150	2150	0	2150.0	1246.3	508.8
		23 OSTRACODA	0	860	2150	1290	2580	0	1146.7	1076.4	439.5
		24 HIRUDINEA	43	86	43	0	0	0	28.7	35.1	14.3

Grand Sum = 85613   Mean = 14268.8   Std.Dev. = 5682.7   Std.Err = 2320.0

Appendix C. Collection records for each larval fish sample including station, time, water volume filtered (m^3), and number of larvae of each taxa.

```
    STATION     S 1             DATE: 04/23/84
    REPLICATE                       1        2         TOTAL
    TIME                         2015     2015
    VOL FILTERED                 40.4     43.3          83.7
    --------------------------------------------------------
    SPECIES                               NUMBER
Lake herring ........               4        6            10
Lake whitefish ......               0        1             1
                                 ----     ----          ----
          TOTALS                    4        7            11




    STATION     S 2             DATE: 04/23/84
    REPLICATE                       1        2         TOTAL
    TIME                         2350     2350
    VOL FILTERED                 33.0     35.5          68.6
    --------------------------------------------------------
    SPECIES                               NUMBER
Lake herring ........               1        1             2
Lake whitefish ......               1        1             2
                                 ----     ----          ----
          TOTALS                    2        2             4




    STATION     S 3             DATE: 04/23/84
    REPLICATE                       1        2         TOTAL
    TIME                         2325     2325
    VOL FILTERED                 36.9     39.4          76.3
    --------------------------------------------------------
    SPECIES                               NUMBER
Lake herring ........               1        1             2
                                 ----     ----          ----
          TOTALS                    1        1             2




    STATION     S 4             DATE: 04/23/84
    REPLICATE                       1        2         TOTAL
    TIME                         2250     2250
    VOL FILTERED                 34.4     35.9          70.3
    --------------------------------------------------------
         NO  FISH  CAPTURED
```

```
     STATION      S 5            DATE: 04/23/84
     REPLICATE                           1         2          TOTAL
     TIME                             2115      2115
     VOL FILTERED                     41.1      43.2           84.3
     -------------------------------------------------------------
     SPECIES                                  NUMBER
Lake herring ........                    4         1              5
Lake whitefish ......                    0         2              2
                                      ----      ----           ----
           TOTALS                        4         3              7
```

```
     STATION      S 6            DATE: 04/23/84
     REPLICATE                           1         2          TOTAL
     TIME                             2210      2210
     VOL FILTERED                     44.1      46.1           90.2
     -------------------------------------------------------------
     SPECIES                                  NUMBER
Burbot ..............                    1         0              1
Lake herring ........                    0         2              2
Lake whitefish ......                    1         0              1
Pink salmon..........                    0         1              1
                                      ----      ----           ----
           TOTALS                        2         3              5
```

```
     STATION      S 7            DATE: 04/23/84
     REPLICATE                           1         2          TOTAL
     TIME                             2150      2150
     VOL FILTERED                     36.3      37.8           74.1
     -------------------------------------------------------------
     SPECIES                                  NUMBER
Lake herring ........                    1         0              1
                                      ----      ----           ----
           TOTALS                        1         0              1
```

125

```
    STATION     C 2          DATE: 04/24/84
    REPLICATE                    1         2        TOTAL
    TIME                      2340      2350
    VOL FILTERED              89.0     112.6        201.6
    ---------------------------------------------------
    SPECIES                             NUMBER
Lake herring ........            0         3            3
                              ----      ----         ----
          TOTALS                 0         3            3


    STATION     L 1          DATE: 04/24/84
    REPLICATE                    1         2        TOTAL
    TIME                      2010      2015
    VOL FILTERED               2.5       2.5          5.0
    ---------------------------------------------------
         NO FISH CAPTURED


    STATION     C 3          DATE: 04/24/84
    REPLICATE                    1         2        TOTAL
    TIME                      2300      2310
    VOL FILTERED             123.6     112.3        235.8
    ---------------------------------------------------
    SPECIES                             NUMBER
Lake herring ........            2         2            4
                              ----      ----         ----
          TOTALS                 2         2            4


    STATION     L 2          DATE: 04/24/84
    REPLICATE                    1         2        TOTAL
    TIME                      0015      0015
    VOL FILTERED               4.0       2.5          6.5
    ---------------------------------------------------
    SPECIES                             NUMBER
Lake herring ........            1         0            1
Lake whitefish ......            2         0            2
                              ----      ----         ----
          TOTALS                 3         0            3
```

```
     STATION      L 8            DATE: 04/24/84
     REPLICATE                           1          2           TOTAL
     TIME                             2155       2155
     VOL FILTERED                      4.1        4.1             8.2
     -------------------------------------------------------------
     SPECIES                                   NUMBER
Lake whitefish ......                    0          1               1
                                      ----       ----            ----
            TOTALS                       0          1               1



     STATION      C 2            DATE: 05/08/84
     REPLICATE                           1          2           TOTAL
     TIME                             2340       2350
     VOL FILTERED                     98.2      122.6           220.8
     -------------------------------------------------------------
     SPECIES                                   NUMBER
Burbot ..............                    6          4              10
                                      ----       ----            ----
            TOTALS                       6          4              10



     STATION      L 1            DATE: 05/08/84
     REPLICATE                           1          2           TOTAL
     TIME                             2115       2125
     VOL FILTERED                      1.5        1.9             3.4
     -------------------------------------------------------------
     SPECIES                                   NUMBER
Unidentifiable ......                    0          1               1
                                      ----       ----            ----
            TOTALS                       0          1               1



     STATION      S 1            DATE: 05/08/84
     REPLICATE                           1          2           TOTAL
     TIME                             2130       2130
     VOL FILTERED                     39.8       40.8            80.6
     -------------------------------------------------------------
     SPECIES                                   NUMBER
Yellow perch ........                    4          2               6
Rainbow smelt .......                    1          3               4
Lake herring ........                    5          2               7
                                      ----       ----            ----
            TOTALS                      10          7              17
     STATION      C 3             DATE: 05/08/84
     REPLICATE                        1          2            TOTAL
     TIME                          2320       2330
     VOL FILTERED                 103.3      102.1            205.4
     ------------------------------------------------------------
     SPECIES                                NUMBER
Burbot ..............                 6          5               11
Lake whitefish ......                 1          0                1
                                   ----       ----             ----
           TOTALS                     7          5               12



     STATION      L 2             DATE: 05/08/84
     REPLICATE                        1          2            TOTAL
     TIME                          0005       0015
     VOL FILTERED                   2.2        2.9              5.1
     ------------------------------------------------------------
     SPECIES                                NUMBER
Lake whitefish ......                 0          1                1
                                   ----       ----             ----
           TOTALS                     0          1                1



     STATION      C 7             DATE: 05/08/84
     REPLICATE                        1          2            TOTAL
     TIME                          2240       2310
     VOL FILTERED                  87.8       89.7            177.4
     ------------------------------------------------------------
     SPECIES                                NUMBER
Burbot ..............                 0          5                5
                                   ----       ----             ----
           TOTALS                     0          5                5



     STATION      S 3             DATE: 05/08/84
     REPLICATE                        1          2            TOTAL
     TIME                          2350       2350
     VOL FILTERED                  42.5       44.1             86.6
     ------------------------------------------------------------
     SPECIES                                NUMBER
Burbot ..............                 2          7                9
Lake herring ........                 0          1                1
                                   ----       ----             ----
           TOTALS                     2          8               10
```

STATION L 8 DATE: 05/08/84

REPLICATE	1	2	TOTAL
TIME	2330	2330	
VOL FILTERED	1.4	0.9	2.3
SPECIES		NUMBER	
Yellow perch	2	9	11
Lake whitefish	2	1	3
TOTALS	4	10	14

STATION S 4 DATE: 05/08/84

REPLICATE	1	2	TOTAL
TIME	2330	2330	
VOL FILTERED	43.2	46.9	90.1
SPECIES		NUMBER	
Burbot	0	1	1
Lake herring	1	0	1
TOTALS	1	1	2

STATION S 5 DATE: 05/08/84

REPLICATE	1	2	TOTAL
TIME	2225	2225	
VOL FILTERED	40.8	44.6	85.5
SPECIES		NUMBER	
Burbot	0	1	1
Rainbow smelt	1	3	4
TOTALS	1	4	5

```
          STATION      S 6            DATE: 05/08/84
          REPLICATE                         1           2          TOTAL
          TIME                           2305        2305
          VOL FILTERED                   41.4        45.1           86.4
          ------------------------------------------------------------
          SPECIES                                  NUMBER
     Burbot ..............                  4           3              7
                                         ----        ----           ----
                 TOTALS                     4           3              7


          STATION      S 7            DATE: 05/08/84
          REPLICATE                         1           2          TOTAL
          TIME                           2245        2245
          VOL FILTERED                   39.9        43.4           83.4
          ------------------------------------------------------------
          SPECIES                                  NUMBER
     Yellow perch ........                  2           1              3
     Burbot ..............                  7           3             10
     Rainbow smelt .......                  4           2              6
     Lake herring ........                  1           0              1
     Lake whitefish ......                  1           1              2
                                         ----        ----           ----
                 TOTALS                    15           7             22


          STATION      S 8            DATE: 05/08/84
          REPLICATE                         1           2          TOTAL
          TIME                           2200        2200
          VOL FILTERED                   41.7        46.0           87.7
          ------------------------------------------------------------
          SPECIES                                  NUMBER
     Burbot ..............                  1           2              3
                                         ----        ----           ----
                 TOTALS                     1           2              3
          STATION     S 2            DATE: 05/09/84
          REPLICATE                         1          2          TOTAL
          TIME                           0015       0015
          VOL FILTERED                   39.9       40.8           80.7
          -------------------------------------------------------------
          SPECIES                                  NUMBER
      Lake herring ........                17         23             40
      Lake whitefish ......                 6          1              7
      Pink salmon..........                 0          1              1
                                         ----       ----           ----
               TOTALS                      23         25             48
```

```
          STATION     C 2            DATE: 05/22/84
          REPLICATE                         1          2          TOTAL
          TIME                           0015       0015
          VOL FILTERED                  100.1      110.8          210.9
          -------------------------------------------------------------
          SPECIES                                  NUMBER
      Yellow perch ........                 1          0              1
      Lake whitefish ......                 0          2              2
      Pink salmon..........                 0          1              1
                                         ----       ----           ----
               TOTALS                       1          3              4
```

```
          STATION     L 1            DATE: 05/22/84
          REPLICATE                         1          2          TOTAL
          TIME                           0005       0015
          VOL FILTERED                    1.4        1.8            3.2
          -------------------------------------------------------------
          SPECIES                                  NUMBER
      Yellow perch ........                21         26             47
      Logperch ............                 0          1              1
      Lake herring ........                 1          0              1
      Lake whitefish ......                 1          0              1
                                         ----       ----           ----
               TOTALS                      23         27             50
```

```
    STATION      S 1           DATE: 05/22/84
    REPLICATE                     1         2       TOTAL
    TIME                       2135      2135
    VOL FILTERED               41.8      41.9        83.8
    ---------------------------------------------------
    SPECIES                              NUMBER
Walleye .............             9         6          15
Yellow perch ........           192       228         420
Logperch ............             2         1           3
Rainbow smelt .......             5         8          13
Lake herring ........             4         3           7
Lake whitefish ......             1         0           1
                               ----      ----        ----
          TOTALS                213       246         459
```

```
    STATION      C 3           DATE: 05/22/84
    REPLICATE                     1         2       TOTAL
    TIME                       2330      2350
    VOL FILTERED              111.8     109.4       221.2
    ---------------------------------------------------
    SPECIES                              NUMBER
Yellow perch ........             1         0           1
Burbot ..............             1         0           1
Rainbow smelt .......             3         0           3
                               ----      ----        ----
          TOTALS                  5         0           5
```

```
    STATION      L 2           DATE: 05/22/84
    REPLICATE                     1         2       TOTAL
    TIME                       0115      0015
    VOL FILTERED                2.1       2.1         4.1
    ---------------------------------------------------
    SPECIES                              NUMBER
Rainbow smelt .......             2         1           3
Lake whitefish ......             0         1           1
Unidentifiable ......             1         0           1
                               ----      ----        ----
          TOTALS                  3         2           5
          STATION      C 7          DATE: 05/22/84
          REPLICATE                      1         2        TOTAL
          TIME                        2300      2300
          VOL FILTERED                99.1     111.4        210.5
          ------------------------------------------------------
          SPECIES                               NUMBER
      Rainbow smelt .......              1         0            1
      Fourhorn sculpin ....              1         0            1
                                      ----      ----         ----
               TOTALS                    2         0            2



          STATION      S 3          DATE: 05/22/84
          REPLICATE                      1         2        TOTAL
          TIME                        2345      2345
          VOL FILTERED                40.9      41.3         82.2
          ------------------------------------------------------
          SPECIES                               NUMBER
      Burbot ..............              0         1            1
      Rainbow smelt .......              3         2            5
      Lake whitefish ......              1         0            1
                                      ----      ----         ----
               TOTALS                    4         3            7



          STATION      L 8          DATE: 05/22/84
          REPLICATE                      1         2        TOTAL
          TIME                        9999      9999
          VOL FILTERED                 2.2       1.3          3.5
          ------------------------------------------------------
          SPECIES                               NUMBER
      Yellow perch ........             30        40           70
      Iowa darter .........             13         0           13
      Unknown percidae ....              0         2            2
      Unidentifiable ......              0         2            2
                                      ----      ----         ----
               TOTALS                   43        44           87
          STATION      S 4              DATE: 05/22/84
          REPLICATE                        1          2          TOTAL
          TIME                          2320       2320
          VOL FILTERED                  40.3       41.1           81.4
          ------------------------------------------------------------
          SPECIES                                 NUMBER
     Yellow perch ........                 4          2              6
                                        ----       ----           ----
                TOTALS                     4          2              6
```

```
          STATION      S 5              DATE: 05/22/84
          REPLICATE                        1          2          TOTAL
          TIME                          2245       2245
          VOL FILTERED                  41.5       41.7           83.2
          ------------------------------------------------------------
          SPECIES                                 NUMBER
     Walleye .............                 1          0              1
     Yellow perch ........                 5          7             12
     Logperch ............                 0          1              1
     Rainbow smelt .......                 2          3              5
     Lake whitefish ......                 1          0              1
     Pink salmon..........                 0          1              1
                                        ----       ----           ----
                TOTALS                     9         12             21
```

```
          STATION      S 6              DATE: 05/22/84
          REPLICATE                        1          2          TOTAL
          TIME                          2305       2305
          VOL FILTERED                  46.0       46.5           92.5
          ------------------------------------------------------------
          SPECIES                                 NUMBER
     Walleye .............                 0          1              1
     Yellow perch ........                 8          8             16
     Burbot ..............                 1          0              1
     Etheostoma sp. ......                 0          1              1
     Rainbow smelt .......                 3          3              6
     Pink salmon..........                 0          2              2
                                        ----       ----           ----
                TOTALS                    12         15             27
```

134

```
          STATION      S 7            DATE: 05/22/84
          REPLICATE                        1          2        TOTAL
          TIME                          2225       2225
          VOL FILTERED                  43.2       43.5         86.7
          ------------------------------------------------------------
          SPECIES                                NUMBER
     Walleye .............                 4          1            5
     Yellow perch ........                89         62          151
     Logperch ............                 0          3            3
     Etheostoma sp. ......                 0          1            1
     Rainbow smelt .......                 2          5            7
                                        ----       ----         ----
                TOTALS                    95         72          167


          STATION      S 8            DATE: 05/22/84
          REPLICATE                        1          2        TOTAL
          TIME                          2210       2225
          VOL FILTERED                  39.0        0.0         39.0
          ------------------------------------------------------------
          SPECIES                                NUMBER
     Yellow perch ........                14          0           14
     Rainbow smelt .......                10          0           10
     Unidentifiable ......                 1          0            1
                                        ----       ----         ----
                TOTALS                    25          0           25


          STATION      S 2            DATE: 05/23/84
          REPLICATE                        1          2        TOTAL
          TIME                          0010       0010
          VOL FILTERED                  39.5       40.5         80.0
          ------------------------------------------------------------
          SPECIES                                NUMBER
     Yellow perch ........                 1          0            1
     Burbot ..............                 0          1            1
     Rainbow smelt .......                 0          1            1
     Lake whitefish ......                 1          1            2
                                        ----       ----         ----
                TOTALS                     2          3            5
```

```
    STATION     C 2           DATE: 06/04/84
    REPLICATE                    1         2        TOTAL
    TIME                      2345      0005
    VOL FILTERED             110.3     104.6        214.9
    -----------------------------------------------------
    SPECIES                             NUMBER
Yellow perch ........            0         1            1
Rainbow smelt .......           55       189          244
Spottail shiner .....            1         0            1
                              ----      ----         ----
          TOTALS                56       190          246
```

```
    STATION     L 1           DATE: 06/04/84
    REPLICATE                    1         2        TOTAL
    TIME                      2215      2215
    VOL FILTERED               1.1       0.7          1.8
    -----------------------------------------------------
    SPECIES                             NUMBER
Yellow perch ........            5         0            5
Black crappie .......            5         2            7
Spottail shiner .....           12         3           15
                              ----      ----         ----
          TOTALS                22         5           27
```

```
    STATION     S 1           DATE: 06/04/84
    REPLICATE                    1         2        TOTAL
    TIME                      2145      2145
    VOL FILTERED              53.3      53.4        106.7
    -----------------------------------------------------
    SPECIES                             NUMBER
Yellow perch ........           42        49           91
Logperch ............            3         1            4
Rainbow smelt .......            3         6            9
Lake herring ........            6         3            9
Unidentifiable ......            4         3            7
Trout-perch .........            1         0            1
Unknown cyprinidae ..            2         1            3
Spottail shiner .....          148       157          305
                              ----      ----         ----
          TOTALS               209       220          429
```

```
     STATION      S 2             DATE: 06/04/84
     REPLICATE                          1         2        TOTAL
     TIME                            0045      0045
     VOL FILTERED                    30.1      30.5         60.6
     -----------------------------------------------------------
     SPECIES                                 NUMBER
Yellow perch ........                   4         2            6
Unknown percidae ....                   0         1            1
Rainbow smelt .......                  31        26           57
Lake herring ........                   0         2            2
Spottail shiner .....                   2         0            2
                                     ----      ----         ----
           TOTALS                      37        31           68



     STATION      S 3             DATE: 06/04/84
     REPLICATE                          1         2        TOTAL
     TIME                            0030      0030
     VOL FILTERED                    42.9      44.5         87.4
     -----------------------------------------------------------
     SPECIES                                 NUMBER
Yellow perch ........                   1         1            2
Burbot ..............                   0         1            1
Rainbow smelt .......                  49        86          135
                                     ----      ----         ----
           TOTALS                      50        88          138



     STATION      S 4             DATE: 06/04/84
     REPLICATE                          1         2        TOTAL
     TIME                            0000      0000
     VOL FILTERED                    38.3      38.5         76.9
     -----------------------------------------------------------
     SPECIES                                 NUMBER
Yellow perch ........                   1         0            1
Rainbow smelt .......                  45        46           91
Spottail shiner .....                   2         0            2
                                     ----      ----         ----
           TOTALS                      48        46           94
```

STATION S 5	DATE: 06/04/84		
REPLICATE	1	2	TOTAL
TIME	2230	2230	
VOL FILTERED	44.0	44.5	88.4
SPECIES		NUMBER	
Yellow perch	1	2	3
Logperch	1	0	1
Burbot	0	1	1
Rainbow smelt	90	74	164
Unknown catostomidae	0	1	1
White sucker	0	4	4
Bloater	0	2	2
Unidentifiable	1	0	1
Fourhorn sculpin	1	0	1
Spottail shiner	3	1	4
TOTALS	97	85	182

STATION S 6	DATE: 06/04/84		
REPLICATE	1	2	TOTAL
TIME	2330	2330	
VOL FILTERED	41.5	42.1	83.6
SPECIES		NUMBER	
Yellow perch	1	0	1
Rainbow smelt	88	119	207
TOTALS	89	119	208

STATION S 7	DATE: 06/04/84		
REPLICATE	1	2	TOTAL
TIME	2300	2300	
VOL FILTERED	34.2	35.6	69.9
SPECIES		NUMBER	
Walleye	1	0	1
Yellow perch	21	28	49
Logperch	0	1	1
Rainbow smelt	22	35	57
Spottail shiner	0	1	1
TOTALS	44	65	109

```
          STATION      S 8             DATE: 06/04/84
          REPLICATE                       1         2         TOTAL
          TIME                         2215      2215
          VOL FILTERED                 49.0      34.8          83.8
          ---------------------------------------------------------
          SPECIES                               NUMBER
      Yellow perch ........               0         2             2
      Rainbow smelt .......               9        23            32
      Unidentifiable ......               1         1             2
      Spottail shiner .....               3         2             5
                                       ----      ----          ----
                TOTALS                   13        28            41



          STATION      C 3             DATE: 06/05/84
          REPLICATE                       1         2         TOTAL
          TIME                         0030      0035
          VOL FILTERED                 94.0     103.4         197.3
          ---------------------------------------------------------
          SPECIES                               NUMBER
      Yellow perch ........               0         1             1
      Burbot ..............               0         4             4
      Rainbow smelt .......              90       150           240
                                       ----      ----          ----
                TOTALS                   90       155           245



          STATION      L 2             DATE: 06/05/84
          REPLICATE                       1         2         TOTAL
          TIME                         0130      0130
          VOL FILTERED                  0.7       2.0           2.7
          ---------------------------------------------------------
          SPECIES                               NUMBER
      Yellow perch ........               5         0             5
      Unknown percidae ....               2         0             2
      Unidentifiable ......               1         0             1
                                       ----      ----          ----
                TOTALS                    8         0             8
```

```
         STATION      C 7            DATE: 06/05/84
         REPLICATE                      1         2         TOTAL
         TIME                        0100      0105
         VOL FILTERED                97.0     104.4         201.3
         ---------------------------------------------------------
         SPECIES                             NUMBER
     Burbot ..............              1         0             1
     Rainbow smelt .......            231        43           274
                                     ----      ----          ----
               TOTALS                 232        43           275
```

```
         STATION      L 8            DATE: 06/05/84
         REPLICATE                      1         2         TOTAL
         TIME                        2315      2315
         VOL FILTERED                 1.5       2.2           3.7
         ---------------------------------------------------------
         SPECIES                             NUMBER
     Yellow perch ........              0        13            13
     Unknown percidae ....              0         4             4
                                     ----      ----          ----
               TOTALS                   0        17            17
```

```
         STATION      L 1            DATE: 06/19/84
         REPLICATE                      1         2         TOTAL
         TIME                        2200      2200
         VOL FILTERED                 0.8       1.7           2.4
         ---------------------------------------------------------
         SPECIES                             NUMBER
     Yellow perch ........              1         1             2
     Logperch ............              2         0             2
     Unknown percidae ....              0         3             3
     Unidentifiable ......              5         0             5
     Lepomis sp. .........              2         1             3
     Black crappie .......            102        37           139
                                     ----      ----          ----
               TOTALS                 112        42           154
```

```
        STATION      S 1             DATE: 06/19/84
        REPLICATE                          1         2         TOTAL
        TIME                            2156      2156
        VOL FILTERED                    41.2      41.0          82.2
        ----------------------------------------------------------------
        SPECIES                                 NUMBER
    Yellow perch ........                  3         2             5
    Logperch ............                  1         0             1
    Moxostoma sp. .......                  0         1             1
    Lake herring ........                  1         0             1
    Black crappie .......                 27        45            72
                                        ----      ----          ----
             TOTALS                       32        48            80


        STATION      L 2             DATE: 06/19/84
        REPLICATE                          1         2         TOTAL
        TIME                            2250      2250
        VOL FILTERED                     1.4       1.7           3.1
        ----------------------------------------------------------------
        SPECIES                                 NUMBER
    Yellow perch ........                  0         3             3
    Unknown percidae ....                  1         0             1
    Unidentifiable ......                  0         2             2
    Lepomis sp. .........                  8         8            16
    Spottail shiner .....                  1         0             1
    Golden shiner .......                  0         1             1
                                        ----      ----          ----
             TOTALS                       10        14            24


        STATION      C 7             DATE: 06/19/84
        REPLICATE                          1         2         TOTAL
        TIME                            2330      2340
        VOL FILTERED                    90.5      85.0         175.5
        ----------------------------------------------------------------
        SPECIES                                 NUMBER
    Rainbow smelt .......                  4         0             4
                                        ----      ----          ----
             TOTALS                        4         0             4
    STATION     L 3            DATE: 06/19/84
    REPLICATE                         1          2        TOTAL
    TIME                           0030       0040
    VOL FILTERED                    2.3        2.7          5.0
    ---------------------------------------------------------
         NO  FISH  CAPTURED


    STATION     S 4            DATE: 06/19/84
    REPLICATE                         1          2        TOTAL
    TIME                           2355       2355
    VOL FILTERED                   44.8       47.4         92.2
    ---------------------------------------------------------
    SPECIES                                 NUMBER
Yellow perch ........                 1          0            1
Rainbow smelt .......                 1          8            9
Unidentifiable ......                 1          0            1
                                   ----       ----         ----
           TOTALS                     3          8           11


    STATION     S 6            DATE: 06/19/84
    REPLICATE                         1          2        TOTAL
    TIME                           2335       2335
    VOL FILTERED                   45.3       45.1         90.4
    ---------------------------------------------------------
    SPECIES                                 NUMBER
Rainbow smelt .......                 3          3            6
Spottail shiner .....                 0          8            8
                                   ----       ----         ----
           TOTALS                     3         11           14
```

STATION S 7	DATE:	06/19/84	
REPLICATE	1	2	TOTAL
TIME	2317	2317	
VOL FILTERED	17.6	35.5	53.1
SPECIES		NUMBER	
Yellow perch	8	11	19
Johnny darter	5	6	11
Rainbow smelt	7	11	18
Spottail shiner	0	6	6
TOTALS	20	34	54

STATION S 8	DATE:	06/19/84	
REPLICATE	1	2	TOTAL
TIME	2216	2216	
VOL FILTERED	52.4	51.2	103.7
SPECIES		NUMBER	
Yellow perch	13	11	24
Johnny darter	6	8	14
Rainbow smelt	3	3	6
Unknown centrarchidae	1	0	1
Spottail shiner	3	0	3
TOTALS	26	22	48

STATION C 2	DATE:	06/20/84	
REPLICATE	1	2	TOTAL
TIME	0050	0100	
VOL FILTERED	98.5	103.8	202.3
SPECIES		NUMBER	
Yellow perch	0	1	1
Burbot	0	3	3
Rainbow smelt	5	8	13
TOTALS	5	12	17

```
     STATION      C 3          DATE: 06/20/84
     REPLICATE                        1         2         TOTAL
     TIME                          0005      0005
     VOL FILTERED                  93.4      97.8         191.2
     -----------------------------------------------------------
     SPECIES                                NUMBER
Yellow perch ........                 0         1             1
Burbot ..............                 1         0             1
Rainbow smelt .......                15         9            24
                                   ----      ----          ----
          TOTALS                     16        10            26


     STATION      S 2          DATE: 06/20/84
     REPLICATE                        1         2         TOTAL
     TIME                          0042      0042
     VOL FILTERED                  43.6      44.3          87.9
     -----------------------------------------------------------
     SPECIES                                NUMBER
Yellow perch ........                 0         1             1
Burbot ..............                 1         1             2
Rainbow smelt .......                 5         7            12
                                   ----      ----          ----
          TOTALS                      6         9            15


     STATION      S 3          DATE: 06/20/84
     REPLICATE                        1         2         TOTAL
     TIME                          0022      0022
     VOL FILTERED                  42.2      42.8          85.0
     -----------------------------------------------------------
     SPECIES                                NUMBER
Yellow perch ........                 1         0             1
Burbot ..............                 0         1             1
Rainbow smelt .......                 6         1             7
                                   ----      ----          ----
          TOTALS                      7         2             9
```

```
         STATION      S 5             DATE: 06/20/84
         REPLICATE                            1          2         TOTAL
         TIME                              2237       2237
         VOL FILTERED                      44.6       43.9          88.5
         -------------------------------------------------------------
         SPECIES                                    NUMBER
     Yellow perch ........                    1          1             2
     Johnny darter .......                    1          4             5
     Rainbow smelt .......                    9         10            19
     Lake herring ........                    0          1             1
     Trout-perch .........                    2          0             2
     Black crappie .......                    0          1             1
     Unknown cyprinidae ..                    0          1             1
     Spottail shiner .....                   46         39            85
                                           ----       ----          ----
               TOTALS                        59         57           116
```

```
         STATION      L 1             DATE: 07/03/84
         REPLICATE                            1          2         TOTAL
         TIME                              2200       2200
         VOL FILTERED                       0.7        1.9           2.6
         -------------------------------------------------------------
         SPECIES                                    NUMBER
     Yellow perch ........                    0          2             2
     Johnny darter .......                    0          1             1
     Unknown percidae ....                    0          2             2
     Lepomis sp. .........                    5          5            10
     Lepomis sp. .........                    1          6             7
     Unknown cyprinidae ..                    1          0             1
     Carp ................                    2          0             2
     Spottail shiner .....                    0         15            15
                                           ----       ----          ----
               TOTALS                         9         31            40
     STATION      S 1              DATE: 07/03/84
     REPLICATE                          1          2        TOTAL
     TIME                            2148       2148
     VOL FILTERED                    47.9       48.7         96.6
     --------------------------------------------------------
     SPECIES                                  NUMBER
Yellow perch ........                   0          3            3
Logperch ............                   0          3            3
Lepomis sp. .........                   1          0            1
Rock bass ...........                   1          0            1
Gizzard shad ........                   1          0            1
Carp ................                   3          0            3
                                     ----       ----         ----
           TOTALS                       6          6           12
```

```
     STATION      C 7              DATE: 07/03/84
     REPLICATE                          1          2        TOTAL
     TIME                            2315       2148
     VOL FILTERED                   108.1        0.0        108.1
     --------------------------------------------------------
     SPECIES                                  NUMBER
Logperch ............                   1          0            1
Rainbow smelt .......                   2          0            2
Emerald shiner ......                   8          0            8
                                     ----       ----         ----
           TOTALS                      11          0           11
```

```
     STATION      L 8              DATE: 07/03/84
     REPLICATE                          1          2        TOTAL
     TIME                            2240       2240
     VOL FILTERED                     2.0        1.1          3.1
     --------------------------------------------------------
     SPECIES                                  NUMBER
Yellow perch ........                   3          0            3
Johnny darter .......                   1          0            1
Lepomis sp. .........                  98         42          140
Unknown cyprinidae ..                   8          1            9
Carp ................                   3         25           28
Emerald shiner ......                   1          0            1
Spottail shiner .....                   5          0            5
Golden shiner .......                   4          8           12
                                     ----       ----         ----
           TOTALS                     123         76          199
```

STATION S 3 DATE: 07/03/84

REPLICATE	1	2	TOTAL
TIME	2354	2354	
VOL FILTERED	47.0	47.2	94.2
SPECIES		NUMBER	
Yellow perch	0	2	2
Logperch	1	2	3
Rainbow smelt	0	1	1
Ninespine stickleback	0	1	1
Cottus sp.	1	0	1
Carp	0	1	1
TOTALS	2	7	9

STATION S 4 DATE: 07/03/84

REPLICATE	1	2	TOTAL
TIME	2340	2340	
VOL FILTERED	43.1	44.2	87.3
SPECIES		NUMBER	
Logperch	1	3	4
Rainbow smelt	2	3	5
Unknown cyprinidae ..	2	0	2
Carp	1	0	1
Spottail shiner	0	1	1
TOTALS	6	7	13

STATION S 5 DATE: 07/03/84

REPLICATE	1	2	TOTAL
TIME	2230	2230	
VOL FILTERED	45.9	46.5	92.5
SPECIES		NUMBER	
Yellow perch	0	2	2
Johnny darter	4	2	6
Logperch	1	2	3
Rainbow smelt	3	3	6
Unknown cyprinidae ..	3	1	4
Carp	20	30	50
Spottail shiner	32	21	53
TOTALS	63	61	124

```
     STATION      S 6             DATE: 07/03/84
     REPLICATE                       1          2          TOTAL
     TIME                         2320       2320
     VOL FILTERED                 42.1       41.4           83.5
     -----------------------------------------------------------
     SPECIES                                NUMBER
Johnny darter .......                1          0              1
Logperch ............                3          2              5
Rainbow smelt .......                2          3              5
Trout-perch .........                0          1              1
Carp ................                9          8             17
Spottail shiner .....                1          1              2
Mimic shiner ........                0          1              1
                                  ----       ----           ----
            TOTALS                  16         16             32
```

```
     STATION      S 7             DATE: 07/03/84
     REPLICATE                       1          2          TOTAL
     TIME                         2300       2300
     VOL FILTERED                 51.6       51.0          102.6
     -----------------------------------------------------------
     SPECIES                                NUMBER
Johnny darter .......                0          1              1
Logperch ............                3          3              6
Unknown percidae ....                0          1              1
Rainbow smelt .......                3          6              9
Carp ................                3          1              4
Spottail shiner .....                4          8             12
                                  ----       ----           ----
            TOTALS                  13         20             33
```

```
     STATION      S 8             DATE: 07/03/84
     REPLICATE                       1          2          TOTAL
     TIME                         2214       2214
     VOL FILTERED                 43.1       44.4           87.4
     -----------------------------------------------------------
     SPECIES                                NUMBER
Rainbow smelt .......                2          6              8
Pimephales sp. ......                1          0              1
Carp ................                3          3              6
Emerald shiner ......                1          0              1
Spottail shiner .....                3          4              7
                                  ----       ----           ----
            TOTALS                  10         13             23
```

128

```
    STATION     C 2         DATE: 07/04/84
    REPLICATE                    1         2         TOTAL
    TIME                      0110      0120
    VOL FILTERED             104.1     114.3         218.4
    ----------------------------------------------------
    SPECIES                           NUMBER
Yellow perch ........            1         0             1
Johnny darter .......            1         1             2
Logperch ............            8         6            14
Rainbow smelt .......            9         9            18
Trout-perch .........            1         1             2
                              ----      ----          ----
      TOTALS                    20        17            37
```

```
    STATION     C 3         DATE: 07/04/84
    REPLICATE                    1         2         TOTAL
    TIME                      0045      0045
    VOL FILTERED             103.2     102.7         205.9
    ----------------------------------------------------
    SPECIES                           NUMBER
Yellow perch ........            0         1             1
Johnny darter .......            0         1             1
Logperch ............            2         1             3
Rainbow smelt .......            5         4             9
Unidentifiable ......            1         0             1
Lepomis sp. .........            0         1             1
                              ----      ----          ----
      TOTALS                     8         8            16
```

```
    STATION     L 2         DATE: 07/04/84
    REPLICATE                    1         2         TOTAL
    TIME                      0020      0020
    VOL FILTERED               2.7       2.8           5.6
    ----------------------------------------------------
    SPECIES                           NUMBER
Logperch ............            1         0             1
Lepomis sp. .........            2         0             2
Unknown cyprinidae ..            2         0             2
Spottail shiner .....            1         5             6
                              ----      ----          ----
      TOTALS                     6         5            11
```

STATION S 2	DATE: 07/04/84		
REPLICATE	1	2	TOTAL
TIME	0020	0020	
VOL FILTERED	45.0	45.1	90.1
SPECIES		NUMBER	
Yellow perch	1	0	1
Johnny darter	0	1	1
Logperch	1	4	5
Etheostoma sp.	1	0	1
Rainbow smelt	0	1	1
Trout-perch	1	0	1
Spottail shiner	1	0	1
TOTALS	5	6	11

STATION C 7	DATE: 07/04/84		
REPLICATE	1	2	TOTAL
TIME	2320	2330	
VOL FILTERED	100.1	104.4	204.5
SPECIES		NUMBER	
Yellow perch	0	1	1
Logperch	5	5	10
Rainbow smelt	5	11	16
Spottail shiner	1	0	1
Mimic shiner	1	0	1
TOTALS	12	17	29

STATION L 1	DATE: 07/23/84		
REPLICATE	1	2	TOTAL
TIME	2200	2200	
VOL FILTERED	2.7	1.9	4.6
SPECIES		NUMBER	
Spottail shiner	1	0	1
Golden shiner	2	0	2
TOTALS	3	0	3

150

STATION S 1	DATE: 07/23/84		
REPLICATE	1	2	TOTAL
TIME	2150	2150	
VOL FILTERED	48.1	48.1	96.2
SPECIES		NUMBER	
Yellow perch	1	0	1
Logperch	0	1	1
Unknown catostomidae	0	1	1
Black crappie	2	3	5
Rock bass	0	2	2
Alewife	1	0	1
Gizzard shad	7	5	12
Emerald shiner	0	3	3
TOTALS	11	15	26

STATION C 3	DATE: 07/23/84		
REPLICATE	1	2	TOTAL
TIME	2350	2350	
VOL FILTERED	97.5	96.7	194.2
SPECIES		NUMBER	
Johnny darter	8	2	10
Logperch	2	0	2
Rainbow smelt	9	5	14
Trout-perch	2	0	2
Brook stickleback ...	0	1	1
Emerald shiner	11	3	14
TOTALS	32	11	43

STATION L 2	DATE: 07/23/84		
REPLICATE	1	2	TOTAL
TIME	0045	0045	
VOL FILTERED	3.8	3.4	7.2
SPECIES		NUMBER	
Johnny darter	1	1	2
Logperch	0	1	1
Etheostoma sp.	15	5	20
Unknown cyprinidae ..	1	0	1
Mimic shiner	6	6	12
TOTALS	23	13	36

```
    STATION     S 2            DATE: 07/23/84
    REPLICATE                         1          2          TOTAL
    TIME                           0015       0015
    VOL FILTERED                   43.7       43.5           87.2
    ---------------------------------------------------------------
    SPECIES                                 NUMBER
Johnny darter .......                 3          0              3
Logperch ............                13         20             33
Unknown percidae ....                 1          0              1
Trout-perch .........                 3          1              4
Unknown cyprinidae ..                 1          0              1
Emerald shiner ......                 1          0              1
                                   ----       ----           ----
          TOTALS                     22         21             43


    STATION     C 7            DATE: 07/23/84
    REPLICATE                         1          2          TOTAL
    TIME                           2320       2320
    VOL FILTERED                   79.9       84.5          164.5
    ---------------------------------------------------------------
    SPECIES                                 NUMBER
Rainbow smelt .......                 1          3              4
Mottled sculpin .....                 0          1              1
Emerald shiner ......                 1          1              2
                                   ----       ----           ----
          TOTALS                      2          5              7


    STATION     L 8            DATE: 07/23/84
    REPLICATE                         1          2          TOTAL
    TIME                           0030       0030
    VOL FILTERED                    1.6        1.6            3.1
    ---------------------------------------------------------------
    SPECIES                                 NUMBER
Unidentifiable ......                 9          8             17
Lepomis sp. .........                 1          4              5
Golden shiner .......                 7         19             26
                                   ----       ----           ----
          TOTALS                     17         31             48
```

152

```
     STATION      S 3           DATE: 07/23/84
     REPLICATE                        1          2         TOTAL
     TIME                          2355       2355
     VOL FILTERED                  46.0       47.4          93.4
     -----------------------------------------------------------
     SPECIES                                NUMBER
Johnny darter .......                12          9            21
Logperch ............                 1          1             2
Rainbow smelt .......                 2          1             3
Emerald shiner ......                 0          1             1
Mimic shiner ........                 0          1             1
                                   ----       ----          ----
           TOTALS                    15         13            28


     STATION      S 4           DATE: 07/23/84
     REPLICATE                        1          2         TOTAL
     TIME                          2320       2320
     VOL FILTERED                  43.9       43.6          87.5
     -----------------------------------------------------------
     SPECIES                                NUMBER
Johnny darter .......                 0          4             4
Logperch ............                 3          3             6
Rainbow smelt .......                 3          2             5
Trout-perch .........                 0          1             1
Unknown cyprinidae ..                 1          1             2
Carp ................                 2          2             4
                                   ----       ----          ----
           TOTALS                     9         13            22


     STATION      S 5           DATE: 07/23/84
     REPLICATE                        1          2         TOTAL
     TIME                          2230       2230
     VOL FILTERED                  41.7       42.8          84.5
     -----------------------------------------------------------
     SPECIES                                NUMBER
Johnny darter .......                 5          0             5
Logperch ............                 0          1             1
Rainbow smelt .......                 1          0             1
Trout-perch .........                 1          0             1
Unknown cyprinidae ..                19         24            43
Carp ................                 4          7            11
Emerald shiner ......                32         72           104
                                   ----       ----          ----
           TOTALS                    62        104           166
```

```
          STATION      S 6             DATE: 07/23/84
          REPLICATE                           1          2          TOTAL
          TIME                             2300       2300
          VOL FILTERED                     42.6       42.9           85.5
          --------------------------------------------------------------
          SPECIES                                   NUMBER
     Johnny darter .......                    0          1              1
     Logperch ............                    2          2              4
     Rainbow smelt .......                    2          2              4
     Unknown cyprinidae ..                    0          7              7
     Carp ................                    2          1              3
     Emerald shiner ......                   44         52             96
                                           ----       ----           ----
                 TOTALS                      50         65            115
```

```
          STATION      S 7             DATE: 07/23/84
          REPLICATE                           1          2          TOTAL
          TIME                             2245       2245
          VOL FILTERED                     45.1       44.6           89.7
          --------------------------------------------------------------
          SPECIES                                   NUMBER
     Yellow perch ........                    0          1              1
     Johnny darter .......                    3          0              3
     Logperch ............                    6          7             13
     Etheostoma sp. ......                    0          1              1
     Rainbow smelt .......                    4          3              7
     Unidentifiable ......                    1          0              1
     Unknown cyprinidae ..                    1         13             14
     Emerald shiner ......                    2          2              4
     Spottail shiner .....                    1          0              1
                                           ----       ----           ----
                 TOTALS                      18         27             45
          STATION      S 3              DATE: 07/23/84
          REPLICATE                          1         2          TOTAL
          TIME                            2220      2220
          VOL FILTERED                    39.5      38.2           77.7
          -----------------------------------------------------------
          SPECIES                                   NUMBER
      Johnny darter .......                  1         4              5
      Logperch ............                  0         1              1
      Rainbow smelt .......                  7        10             17
      Unidentifiable ......                  0         1              1
      Trout-perch .........                  1         0              1
      Gizzard shad ........                  1         0              1
      Unknown cyprinidae ..                  0         1              1
      Emerald shiner ......                  7         3             10
                                          ----      ----           ----
                 TOTALS                     17        20             37


          STATION      C 2              DATE: 07/24/84
          REPLICATE                          1         2          TOTAL
          TIME                            0015      0015
          VOL FILTERED                   102.4      97.0          199.4
          -----------------------------------------------------------
          SPECIES                                   NUMBER
      Johnny darter .......                  1         0              1
      Logperch ............                  1         2              3
      Rainbow smelt .......                  8         2             10
      Unknown catostomidae                   1         0              1
      Alewife .............                  1         0              1
      Unknown cyprinidae ..                  1         0              1
      Carp ................                  2         0              2
      Emerald shiner ......                  3         0              3
                                          ----      ----           ----
                 TOTALS                     18         4             22


          STATION      L 1              DATE: 08/06/84
          REPLICATE                          1         2          TOTAL
          TIME                            2200      2200
          VOL FILTERED                     2.2       0.3            2.5
          -----------------------------------------------------------
          SPECIES                                   NUMBER
      Black crappie .......                  2         0              2
      Rock bass ...........                  0         2              2
                                          ----      ----           ----
                 TOTALS                      2         2              4
```

```
        STATION      S 1              DATE: 08/06/84
        REPLICATE                            1          2          TOTAL
        TIME                              2157       2157
        VOL FILTERED                      53.9       56.3          110.2
        ----------------------------------------------------------------
        SPECIES                                    NUMBER
Logperch ............                        2          1              3
Unidentifiable ......                        1          2              3
Rock bass ...........                        0          1              1
Alewife .............                        1          3              4
Gizzard shad ........                       51         48             99
Unknown cyprinidae ..                       71         51            122
Emerald shiner ......                        9          3             12
Spottail shiner .....                        0          2              2
                                          ----       ----           ----
              TOTALS                       135        111            246


        STATION      C 3              DATE: 08/06/84
        REPLICATE                            1          2          TOTAL
        TIME                              2345       2355
        VOL FILTERED                     110.2      104.8          215.0
        ----------------------------------------------------------------
        SPECIES                                    NUMBER
Johnny darter .......                        1          0              1
Logperch ............                        3          1              4
Rainbow smelt .......                        0          1              1
Trout-perch .........                        0          1              1
Unknown cyprinidae ..                        1          0              1
Carp ................                        0          3              3
Emerald shiner ......                        2          1              3
Spottail shiner .....                        0          1              1
                                          ----       ----           ----
              TOTALS                         7          8             15


        STATION      C 7              DATE: 08/06/84
        REPLICATE                            1          2          TOTAL
        TIME                              2345       2325
        VOL FILTERED                       0.0      106.7          106.7
        ----------------------------------------------------------------
        SPECIES                                    NUMBER
Rainbow smelt .......                        0          6              6
Carp ................                        0          3              3
Emerald shiner ......                        0         10             10
                                          ----       ----           ----
              TOTALS                         0         19             19
```

156

```
          STATION      L 8            DATE: 08/06/84
          REPLICATE                          1          2         TOTAL
          TIME                            2230       2230
          VOL FILTERED                     0.6        0.9           1.5
          ----------------------------------------------------------------
          SPECIES                                  NUMBER
     Yellow perch ........                   1          0             1
     Lepomis sp. .........                   0          2             2
     Unknown cyprinidae ..                   2          4             6
     Golden shiner .......                   1          0             1
                                          ----       ----          ----
                TOTALS                       4          6            10


          STATION      S 3            DATE: 08/06/84
          REPLICATE                          1          2         TOTAL
          TIME                            2345       2345
          VOL FILTERED                    49.6       50.5         100.1
          ----------------------------------------------------------------
          SPECIES                                  NUMBER
     Logperch ............                   2          2             4
     Rainbow smelt .......                   2          7             9
     Unidentifiable ......                   0          1             1
     Unknown cyprinidae ..                   0          1             1
     Carp ................                   6         12            18
     Emerald shiner ......                   7          4            11
                                          ----       ----          ----
                TOTALS                      17         27            44


          STATION      S 4            DATE: 08/06/84
          REPLICATE                          1          2         TOTAL
          TIME                            2318       2318
          VOL FILTERED                    51.9       52.7         104.6
          ----------------------------------------------------------------
          SPECIES                                  NUMBER
     Johnny darter .......                   0          1             1
     Logperch ............                   1          1             2
     Unknown cyprinidae ..                   7         13            20
     Carp ................                   2          2             4
     Emerald shiner ......                  91         99           190
                                          ----       ----          ----
                TOTALS                     101        116           217
```

STATION S 5 DATE: 08/06/84

REPLICATE	1	2	TOTAL
TIME	2229	2229	
VOL FILTERED	59.9	60.0	119.9
SPECIES		NUMBER	
Yellow perch	0	1	1
Johnny darter	0	3	3
Logperch	1	3	4
Rainbow smelt	2	2	4
Unidentifiable	0	4	4
Trout-perch	2	1	3
Gizzard shad	0	1	1
Unknown cyprinidae	46	126	172
Carp	3	2	5
Emerald shiner	178	105	283
Spottail shiner	1	0	1
TOTALS	233	248	481

STATION S 6 DATE: 08/06/84

REPLICATE	1	2	TOTAL
TIME	2300	2300	
VOL FILTERED	44.5	45.4	90.0
SPECIES		NUMBER	
Logperch	1	5	6
Unidentifiable	0	1	1
Trout-perch	1	2	3
Unknown cyprinidae	10	31	41
Carp	2	0	2
Emerald shiner	39	37	76
TOTALS	53	76	129

```
    STATION      S 7          DATE: 08/06/84
    REPLICATE                      1         2         TOTAL
    TIME                        2245      2245
    VOL FILTERED                53.8      39.9          93.7
    ----------------------------------------------------
    SPECIES                             NUMBER
Logperch ............              4         8            12
Trout-perch .........              1         0             1
Unknown cyprinidae ..             36        29            65
Carp ................              1         0             1
Emerald shiner ......             13        23            36
Spottail shiner .....              2         1             3
                                ----      ----          ----
          TOTALS                  57        61           118
```

```
    STATION      S 8          DATE: 08/06/84
    REPLICATE                      1         2         TOTAL
    TIME                        2214      2214
    VOL FILTERED                54.1      53.7         107.8
    ----------------------------------------------------
    SPECIES                             NUMBER
Johnny darter .......              1         0             1
Logperch ............              1         1             2
Rainbow smelt .......              1         0             1
Freshwater drum .....              1         0             1
Gizzard shad ........              1         4             5
Unknown cyprinidae ..             21        12            33
Carp ................              3         0             3
Emerald shiner ......             41        40            81
                                ----      ----          ----
          TOTALS                  70        57           127
```

```
     STATION      C 2            DATE: 08/07/84
     REPLICATE                      1          2      TOTAL
     TIME                        0025       0030
     VOL FILTERED               118.9      132.0      250.9
     ---------------------------------------------------
     SPECIES                           NUMBER
 Johnny darter .......              1          0          1
 Logperch ............              0          1          1
 Rainbow smelt .......              1          0          1
 Unidentifiable ......              2          0          2
 Alewife .............              0          1          1
 Unknown cyprinidae ..              0          1          1
 Carp ................              1          0          1
 Emerald shiner ......              4          0          4
                                 ----       ----       ----
       TOTALS                       9          3         12


     STATION      L 2            DATE: 08/07/84
     REPLICATE                      1          2      TOTAL
     TIME                        0045       0045
     VOL FILTERED                 0.8        1.8        2.6
     ---------------------------------------------------
     SPECIES                           NUMBER
 Logperch ............              0          3          3
 Etheostoma sp. ......              0          1          1
 Emerald shiner ......              1          0          1
 Spottail shiner .....              1          0          1
                                 ----       ----       ----
       TOTALS                       2          4          6


     STATION      S 2            DATE: 08/07/84
     REPLICATE                      1          2      TOTAL
     TIME                        0022       0022
     VOL FILTERED                47.1       47.6       94.7
     ---------------------------------------------------
     SPECIES                           NUMBER
 Logperch ............              1          1          2
 Rainbow smelt .......              1          1          2
 Unknown cyprinidae ..              1          1          2
 Carp ................              7          3         10
 Emerald shiner ......              0          2          2
                                 ----       ----       ----
       TOTALS                      10          8         18
```

```
    STATION     L 1           DATE: 08/20/84
    REPLICATE                        1          2        TOTAL
    TIME                          2130       2130
    VOL FILTERED                   2.0        0.3          2.3
    -----------------------------------------------------------
         NO  FISH  CAPTURED
```

```
    STATION     S 1           DATE: 08/20/84
    REPLICATE                        1          2        TOTAL
    TIME                          2122       2122
    VOL FILTERED                  44.0       46.7         90.7
    -----------------------------------------------------------
    SPECIES                              NUMBER
Gizzard shad ........                1          6            7
Unknown cyprinidae ..                0          2            2
Emerald shiner ......                0          4            4
                                  ----       ----         ----
          TOTALS                     1         12           13
```

```
    STATION     C 3           DATE: 08/20/84
    REPLICATE                        1          2        TOTAL
    TIME                          2300       2300
    VOL FILTERED                 113.2      107.7        220.9
    -----------------------------------------------------------
    SPECIES                              NUMBER
Logperch ............                0          1            1
Rainbow smelt .......                0          3            3
Trout-perch .........                0          2            2
Alewife .............                3          0            3
Unknown cyprinidae ..                0          1            1
                                  ----       ----         ----
          TOTALS                     3          7           10
```

```
     STATION     L 2           DATE: 08/20/84
     REPLICATE                      1         2        TOTAL
     TIME                        2340      2340
     VOL FILTERED                 2.6       3.4          5.9
     --------------------------------------------------------
     SPECIES                             NUMBER
Logperch ............               5         5           10
Etheostoma sp. ......               0         1            4
Rainbow smelt .......               0         5            5
Pimephales sp. ......               1         0            1
Alewife .............               1         1            2
Unknown cyprinidae ..              13         3           20
                                 ----      ----         ----
            TOTALS                 20        22           42
```

```
     STATION     S 2           DATE: 08/20/84
     REPLICATE                      1         2        TOTAL
     TIME                        2331      2340
     VOL FILTERED                51.8       0.0         51.8
     --------------------------------------------------------
     SPECIES                             NUMBER
Logperch ............               1         0            1
Rainbow smelt .......               5         0            5
Trout-perch .........               4         0            4
                                 ----      ----         ----
            TOTALS                 10         0           10
```

```
     STATION     C 7           DATE: 08/20/84
     REPLICATE                      1         2        TOTAL
     TIME                        2235      2235
     VOL FILTERED               111.4     100.1        211.4
     --------------------------------------------------------
     SPECIES                             NUMBER
Johnny darter .......               0         1            1
Trout-perch .........               1         0            1
Emerald shiner ......               2         1            3
                                 ----      ----         ----
            TOTALS                  3         2            5
```

```
          STATION      L 8             DATE: 08/20/84
          REPLICATE                       1           2          TOTAL
          TIME                         2200        2200
          VOL FILTERED                  0.8         0.8            1.6
          ----------------------------------------------------------
          SPECIES                                NUMBER
      Lepomis sp. .........               1           0              1
      Rock bass ...........               0           1              1
      Pimephales sp. ......               2           0              2
      Golden shiner .......               0           7              7
                                       ----        ----           ----
                TOTALS                    3           8             11


          STATION      S 3             DATE: 08/20/84
          REPLICATE                       1           2          TOTAL
          TIME                         2308        2308
          VOL FILTERED                 50.8        51.2          102.0
          ----------------------------------------------------------
          SPECIES                                NUMBER
      Rainbow smelt .......               4           7             11
      Trout-perch .........               0           2              2
      Alewife .............               1           0              1
                                       ----        ----           ----
                TOTALS                    5           9             14


          STATION      S 4             DATE: 08/20/84
          REPLICATE                       1           2          TOTAL
          TIME                         2250        2250
          VOL FILTERED                 45.5        46.8           92.4
          ----------------------------------------------------------
          SPECIES                                NUMBER
      Rainbow smelt .......               2           0              2
      Emerald shiner ......               0           1              1
                                       ----        ----           ----
                TOTALS                    2           1              3
          STATION      S 5          DATE: 08/20/84
          REPLICATE                         1           2        TOTAL
          TIME                           2205        2205
          VOL FILTERED                   51.1        50.8        101.8
          ------------------------------------------------------------
          SPECIES                                  NUMBER
      Logperch ............               0           1            1
      Trout-perch .........               1           0            1
      Unknown cyprinidae ..               6           1            7
      Emerald shiner ......              32          32           64
                                       ----        ----         ----
                TOTALS                   39          34           73
```

```
          STATION      S 6          DATE: 08/20/84
          REPLICATE                         1           2        TOTAL
          TIME                           2235        2235
          VOL FILTERED                   50.9        51.4        102.4
          ------------------------------------------------------------
          SPECIES                                  NUMBER
      Trout-perch .........               1           0            1
      Alewife .............               0           1            1
      Gizzard shad ........               1           0            1
      Unknown cyprinidae ..               1           0            1
      Carp ................               1           0            1
      Emerald shiner ......               1           4            5
                                       ----        ----         ----
                TOTALS                    5           5           10
```

```
          STATION      S 7          DATE: 08/20/84
          REPLICATE                         1           2        TOTAL
          TIME                           2221        2221
          VOL FILTERED                   54.5        54.3        108.8
          ------------------------------------------------------------
          SPECIES                                  NUMBER
      Johnny darter .......               0           1            1
      Logperch ............               1           0            1
      Alewife .............               1           0            1
      Unknown cyprinidae ..               5           3            8
      Emerald shiner ......              38          45           83
                                       ----        ----         ----
                TOTALS                   45          49           94
          STATION     S 8             DATE: 08/20/84
          REPLICATE                        1          2        TOTAL
          TIME                          2149       2149
          VOL FILTERED                  50.6       49.1         99.6
          ----------------------------------------------------------
          SPECIES                               NUMBER
     Rainbow smelt .......                 1          0            1
     Unknown cyprinidae ..                 2          0            2
     Emerald shiner ......                20          3           23
     Mimic shiner ........                 1          0            1
                                        ----       ----         ----
                 TOTALS                   24          3           27
```

```
          STATION     C 2             DATE: 08/21/84
          REPLICATE                        1          2        TOTAL
          TIME                          0000       0000
          VOL FILTERED                  96.5      100.6        197.1
          ----------------------------------------------------------
          SPECIES                               NUMBER
     Etheostoma sp. ......                 0          1            1
     Rainbow smelt .......                 0          1            1
     Trout-perch .........                 2          0            2
     Alewife .............                 0          1            1
                                        ----       ----         ----
                 TOTALS                    2          3            5
```

Appendix D. Catch records of fish collected with trawls in Munuscong Bay, 1984.

Gear : Trawl
Date : 05/30/84
Station : 1

Species	Number	Weight(g)
Walleye	2	174
Yellow Perch	4	12
Johnny Darter	2	2
Logperch	1	2
Northern Pike	5	679
Rainbow Smelt	1	2
Silver Redhorse	2	2932
Trout-perch	96	194
Emerald Shiner	5	4
Spottail Shiner	12	67
Mimic Shiner	2	4
TOTAL	132	4073

Gear : Trawl
Date : 07/05/84
Station : 1

Species	Number	Weight(g)
Walleye	9	3006
Yellow Perch	15	5
Johnny Darter	3	1
Logperch	1	2
Trout-perch	55	159
Rock Bass	2	8
Brown Bullhead	1	514
Spottail Shiner	4	5
Mimic Shiner	2	1
TOTAL	92	3700

Gear : Trawl
Date : 07/26/84
Station : 1

Species	Number	Weight(g)
Walleye	5	408
Yellow Perch	27	138
Johnny Darter	6	5
Logperch	3	6
White Sucker	1	8
Trout-perch	103	372
Black Crappie	21	12
Emerald Shiner	5	5
Spottail Shiner	4	3
TOTAL	175	956

Gear : Trawl
Date : 08/27/84
Station : 1

Species	Number	Weight(g)
Walleye	3	1144
Yellow Perch	3	61
Logperch	1	5
Trout-perch	3	5
Black Crappie	15	27
Pumpkinseed	1	21
Rock Bass	1	9
Spottail Shiner	5	9
TOTAL	32	1280

Gear : Trawl
Date : 05/30/84
Station : 2

Species	Number	Weight(g)
Yellow Perch	2	87
Johnny Darter	1	2
Rainbow Smelt	2	10
Trout-perch	3	23
·TOTAL	8	121

Gear : Trawl
Date : 07/06/84
Station : 2

Species	Number	Weight(g)
Yellow Perch	2	9
Johnny Darter	1	1
Iowa Darter	5	4
Logperch	37	139
Rainbow Smelt	3	11
White Sucker	2	9
Trout-perch	117	917
Ninespine Stickleback	13	18
Mottled Sculpin	4	8
Emerald Shiner	4	29
Spottail Shiner	6	35
TOTAL	194	1179

Gear : Trawl
Date : 07/26/84
Station : 2

Species	Number	Weight(g)
Yellow Perch	21	101
Johnny Darter	2	1
Logperch	4	45
White Sucker	1	750
Trout-perch	4	17
Rock Bass	1	400
Mottled Sculpin	1	4
Sand Shiner	1	3
Emerald Shiner	1	7
Spottail Shiner	6	15
TOTAL	42	1343

Gear : Trawl
Date : 08/27/84
Station : 2

Species	Number	Weight(g)
Yellow Perch	118	530
Johnny Darter	11	15
Logperch	24	96
Northern Pike	1	468
Rainbow Smelt	2	0
White Sucker	16	12
Trout-perch	7	28
Rock Bass	17	39
Smallmouth Bass	1	37
Bluntnose Minnow	61	100
Spottail Shiner	101	290
Mimic Shiner	172	220
TOTAL	531	1834

Gear : Trawl
Date : 05/30/84
Station : 2A

Species	Number	Weight(g)
Iowa Darter	1	1
Northern Pike	1	696
Trout-perch	1	7
Ninespine Stickleback	1	2
TOTAL	4	705

Gear : Trawl
Date : 07/06/84
Station : 2A

Species	Number	Weight(g)
Walleye	1	3150
Yellow Perch	21	546
Johnny Darter	2	1
Iowa Darter	2	2
Logperch	2	3
Rainbow Smelt	5	42
White Sucker	1	891
Trout-perch	28	171
Rock Bass	1	1
Brook Stickleback	2	2
Mottled Sculpin	9	12
Emerald Shiner	1	8
Spottail Shiner	2	9
TOTAL	77	4838

Gear : Trawl
Date : 07/26/84
Station : 2A

Species	Number	Weight(g)
Walleye	1	390
Yellow Perch	66	720
Johnny Darter	2	1
Logperch	1	2
Rainbow Smelt	2	1
White Sucker	3	849
Trout-perch	4	10
Brook Stickleback	1	1
Mottled Sculpin	2	6
Sand Shiner	8	16
Spottail Shiner	11	36
TOTAL	101	2032

Gear : Trawl
Date : 08/27/84
Station : 2A

Species	Number	Weight(g)
Walleye	1	0
Yellow Perch	154	670
Johnny Darter	32	28
Logperch	4	3
Northern Pike	2	274
White Sucker	9	0
Trout-perch	2	9
Rock Bass	9	613
Ninespine Stickleback	3	1
Mottled Sculpin	28	15
Bluntnose Minnow	8	13
Spottail Shiner	133	380
Mimic Shiner	763	1300
TOTAL	1148	3306

Gear : Trawl
Date : 05/30/84
Station : 3

Species	Number	Weight(g)
Johnny Darter	6	3
White Sucker	1	973
Trout-perch	9	38
Rock Bass	1	1
Mottled Sculpin	1	1
TOTAL	18	1016

Gear : Trawl
Date : 07/06/84
Station : 3

Species	Number	Weight(g)
Yellow Perch	53	1185
Johnny Darter	13	7
Rainbow Smelt	2	12
White Sucker	4	1399
Trout-perch	53	273
Rock Bass	1	1
Mottled Sculpin	6	8
Spottail Shiner	8	45
TOTAL	140	2930

175

Gear : Trawl
Date : 07/26/84
Station : 3

Species	Number	Weight(g)
Yellow Perch	44	1290
Johnny Darter	10	7
Logperch	2	5
White Sucker	4	1692
Trout-perch	44	207
Rock Bass	3	335
Sand Shiner	1	2
Spottail Shiner	20	87
TOTAL	128	3625

Gear : Trawl
Date : 08/27/84
Station : 3

Species	Number	Weight(g)
Yellow Perch	116	490
Johnny Darter	3	4
Logperch	15	50
Rainbow Smelt	4	0
White Sucker	1	2
Trout-perch	11	48
Black Crappie	1	3
Pumpkinseed	2	8
Rock Bass	1	7
Ninespine Stickleback	1	1
Mottled Sculpin	1	1
Spottail Shiner	58	200
Mimic Shiner	77	13
TOTAL	291	826

Gear : Trawl
Date : 05/30/84
Station : 4

Species	Number	Weight(g)
Yellow Perch	1	32
Johnny Darter	21	14
Iowa Darter	4	4
Burbot	2	2109
Rainbow Smelt	1	2
White Sucker	1	615
Lake Whitefish	1	240
Trout-perch	10	84
Rock Bass	1	36
Ninespine Stickleback	2	4
Mottled Sculpin	3	4
Spottail Shiner	3	13
TOTAL	50	3155

Gear : Trawl
Date : 07/06/84
Station : 4

Species	Number	Weight(g)
Walleye	1	490
Yellow Perch	12	415
Johnny Darter	3	2
White Sucker	1	680
Lake Herring	1	2
Trout-perch	214	1271
Ninespine Stickleback	2	3
Spottail Shiner	10	66
TOTAL	244	2929

Gear : Trawl
Date : 07/26/94
Station : 4

Species	Number	Weight(g)
Yellow Perch	158	686
Johnny Darter	24	20
Logperch	1	3
Northern Pike	1	470
White Sucker	1	695
Trout-perch	38	185
Sand Shiner	11	26
Emerald Shiner	1	4
Spottail Shiner	128	303
TOTAL	363	2392

Gear : Trawl
Date : 08/27/84
Station : 4

Species	Number	Weight(g)
Yellow Perch	129	500
Johnny Darter	25	31
Logperch	4	18
Northern Pike	1	438
Rainbow Smelt	2	2
Trout-perch	1	17
Pumpkinseed	1	10
Rock Bass	2	378
Mottled Sculpin	3	12
Emerald Shiner	2	7
Spottail Shiner	31	58
Mimic Shiner	108	152
TOTAL	309	1622

Gear : Trawl
Date : 05/30/84
Station : 7

Species	Number	Weight(g)
Walleye	1	86
Johnny Darter	7	8
Lake Herring	1	147
Trout-perch	57	387
Mottled Sculpin	1	1
TOTAL	67	629

182

Gear : Trawl
Date : 07/06/84
Station : 7

Species	Number	Weight(g)
Yellow Perch	2	7
Johnny Darter	1	1
Trout-perch	20	163
Ninespine Stickleback	2	3
TOTAL	25	173

Gear : Trawl
Date : 07/26/84
Station : 7

Species	Number	Weight(g)
Logperch	1	6
Rainbow Smelt	7	59
Lake Herring	1	3
Trout-perch	11	59
Spottail Shiner	3	18
TOTAL	23	145

Gear : Trawl
Date : 08/27/84
Station : 7

Species	Number	Weight(g)
Yellow Perch	2	4
Johnny Darter	3	3
Trout-perch	20	56
Spottail Shiner	1	4
TOTAL	26	67

Gear : Trawl
Date : 05/30/84
Station : 7A

Species	Number	Weight(g)
Yellow Perch	16	469
Johnny Darter	21	14
Rainbow Smelt	1	4
White Sucker	6	97
Trout-perch	135	750
Ninespine Stickleback	1	2
Emerald Shiner	1	6
Spottail Shiner	34	258
TOTAL	215	1600

Gear : Trawl
Date : 07/06/84
Station : 7A

Species	Number	Weight(g)
Yellow Perch	36	364
Johnny Darter	18	13
Logperch	5	9
Northern Pike	1	350
White Sucker	10	2329
Trout-perch	187	855
Rock Bass	1	23
Ninespine Stickleback	21	240
Mottled Sculpin	7	21
Spottail Shiner	32	74
TOTAL	318	4279

Gear : Trawl
Date : 07/26/84
Station : 7A

Species	Number	Weight(g)
Walleye	2	94
Yellow Perch	29	236
Johnny Darter	51	40
Logperch	5	27
White Sucker	3	1506
Trout-perch	23	86
Mottled Sculpin	2	8
Emerald Shiner	8	38
Spottail Shiner	404	606
TOTAL	527	2641

188

Gear : Trawl
Date : 08/27/84
Station : 7A

Species	Number	Weight(g)
Yellow Perch	93	900
Johnny Darter	15	18
White Sucker	3	1670
Trout-perch	24	100
Rock Bass	7	1023
Emerald Shiner	2	6
Spottail Shiner	35	102
Mimic Shiner	18	22
TOTAL	197	3841

Gear : Trawl
Date : 05/30/84
Station : 8

Species	Number	Weight(g)
Walleye	2	192
Yellow Perch	1	128
Johnny Darter	16	10
Trout-perch	36	85
Mottled Sculpin	1	2
Emerald Shiner	3	2
TOTAL	59	418

190

Gear : Trawl
Date : 07/05/84
Station : 8

Species	Number	Weight(g)
Yellow Perch	37	8
Northern Pike	1	66
Muskellunge	1	1050
White Sucker	1	34
Trout-perch	131	280
Spottail Shiner	55	83
Mimic Shiner	1	3
TOTAL	227	1525

Gear : Trawl
Date : 07/26/84
Station : 8

Species	Number	Weight(g)
Walleye	1	960
Yellow Perch	20	65
Johnny Darter	39	27
Logperch	1	1
Trout-perch	269	540
Sand Shiner	19	11
Spottail Shiner	31	45
TOTAL	380	1649

Appendix E. Catch records of fish taken with large trap nets including numbers tagged from Munuscong Bay, 1984.

Gear : Large Trapnet
Date : 04/25/84
Station : 2L

Species	Number	Tagged
Yellow Perch	12	12
Northern Pike	1	1
Bowfin	1	0
White Sucker	28	0
Silver Redhorse	8	0
TOTAL	50	13

Gear : Large Trapnet
Date : 05/14/84
Station : 2L

Species	Number	Tagged
Walleye	17	16
Yellow Perch	3	3
Northern Pike	4	3
White Sucker	20	0
Silver Redhorse	32	0
Black Crappie	1	1
Rock Bass	3	3
Smallmouth Bass	1	1
Carp	1	0
TOTAL	82	27

194

Gear : Large Trapnet
Date : 06/26/84
Station : 2L

Species	Number	Tagged
Walleye	5	2
Yellow Perch	3	2
Northern Pike	4	4
White Sucker	2	0
Black Crappie	3	3
Channel Catfish	2	0
TOTAL	19	11

Gear : Large Trapnet
Date : 07/11/84
Station : 2L

Species	Number	Tagged
Walleye	42	42
Yellow Perch	8	8
Northern Pike	8	7
Shorthead Redhorse	10	0
White Sucker	85	0
Black Crappie	20	20
Rock Bass	8	8
Smallmouth Bass	3	3
Channel Catfish	16	16
Brown Bullhead	3	1
TOTAL	203	105

Gear : Large Trapnet
Date : 08/07/84
Station : 2L

Species	Number	Tagged
Walleye	1	1
Northern Pike	1	1
White Sucker	39	0
Black Crappie	10	9
Pumpkinseed	1	1
Rock Bass	8	8
Smallmouth Bass	1	1
Brown Bullhead	5	1
TOTAL	66	22

Gear : Large Trapnet
Date : 09/18/84
Station : 2L

Species	Number	Tagged
Walleye	17	8
Muskellunge	1	1
Shorthead Redhorse	2	0
White Sucker	12	0
Silver Redhorse	5	0
Black Crappie	33	12
Pumpkinseed	1	0
Rock Bass	16	4
Smallmouth Bass	10	6
Channel Catfish	6	3
Brown Bullhead	1	1
TOTAL	104	35

Gear : Large Trapnet
Date : 04/24/84
Station : 3L

Species	Number	Tagged
Burbot	5	3
White Sucker	27	0
TOTAL	32	3

Gear : Large Trapnet
Date : 05/17/84
Station : 3L

Species	Number	Tagged
Walleye	1	1
Burbot	2	1
White Sucker	51	0
Rock Bass	2	2
TOTAL	56	4

Gear : Large Trapnet
Date : 06/26/84
Station : 3L

Species	Number	Tagged
Walleye	2	2
Northern Pike	4	4
White Sucker	36	0
Carp	1	0
TOTAL	43	6

Gear : Large Trapnet
Date : 07/11/84
Station : 3L

Species	Number	Tagged
Walleye	8	5
Yellow Perch	10	9
Northern Pike	27	27
Shorthead Redhorse	1	0
White Sucker	118	0
Silver Redhorse	1	0
Lake Whitefish	1	0
Channel Catfish	20	19
Brown Bullhead	2	1
Carp	1	0
TOTAL	189	61

Gear : Large Trapnet
Date : 08/08/84
Station : 3L

Species	Number	Tagged
Walleye	1	1
Yellow Perch	3	3
Northern Pike	5	4
White Sucker	23	0
Silver Redhorse	1	0
Rock Bass	2	1
TOTAL	35	9

Gear : Large Trapnet
Date : 09/18/84
Station : 3L

Species	Number	Tagged
Walleye	1	1
Yellow Perch	2	1
Northern Pike	3	3
White Sucker	17	0
Silver Redhorse	7	0
Lake Whitefish	1	0
Black Crappie	1	0
Rock Bass	1	0
Smallmouth Bass	1	1
Channel Catfish	16	11
Carp	1	0
TOTAL	51	17

199

Gear : Large Trapnet
Date : 04/20/84
Station : 5L

Species	Number	Tagged
Walleye	352	140
Longnose Sucker	1	0
Shorthead Redhorse	2	0
White Sucker	152	0
Silver Redhorse	14	0
Lake Herring	1	0
Channel Catfish	72	0
Brown Bullhead	1	0
TOTAL	595	140

Gear : Large Trapnet
Date : 05/09/84
Station : 5L

Species	Number	Tagged
Walleye	95	87
Northern Pike	21	20
Shorthead Redhorse	8	0
White Sucker	8	0
Silver Redhorse	9	0
Lake Herring	2	0
Channel Catfish	5	5
Carp	1	0
TOTAL	149	112

200

Gear : Large Trapnet
Date : 06/12/84
Station : 5L

Species	Number	Tagged
Walleye	25	0
Yellow Perch	1	0
Northern Pike	6	4
Shorthead Redhorse	8	0
White Sucker	19	0
Silver Redhorse	2	0
Rock Bass	1	1
Smallmouth Bass	1	1
Channel Catfish	3	3
Brown Bullhead	1	0
TOTAL	67	9

Gear : Large Trapnet
Date : 07/11/84
Station : 5L

Species	Number	Tagged
Walleye	33	17
Northern Pike	3	0
Shorthead Redhorse	1	0
Silver Redhorse	4	0
Rock Bass	1	1
Carp	3	0
TOTAL	45	18

Gear : Large Trapnet
Date : 06/08/84
Station : 5L

Species	Number	Tagged
Walleye	59	57
Yellow Perch	2	2
Shorthead Redhorse	9	0
White Sucker	8	0
Silver Redhorse	7	0
Pumpkinseed	9	9
Rock Bass	22	22
Smallmouth Bass	13	13
Channel Catfish	1	0
TOTAL	130	103

Gear : Large Trapnet
Date : 09/18/84
Station : 5L

Species	Number	Tagged
Walleye	15	6
Yellow Perch	2	1
Northern Pike	3	2
Shorthead Redhorse	10	0
White Sucker	9	0
Silver Redhorse	15	0
Lake Herring	1	1
Rock Bass	6	5
Smallmouth Bass	1	1
Channel Catfish	3	2
TOTAL	65	18

Gear : Large Trapnet
Date : 04/20/84
Station : 8L

Species	Number	Tagged
Walleye	118	117
Burbot	2	2
Longnose Sucker	1	0
Shorthead Redhorse	1	0
White Sucker	30	0
Silver Redhorse	1	0
Lake Herring	2	0
Channel Catfish	55	55
TOTAL	210	174

Gear : Large Trapnet
Date : 05/18/84
Station : 8L

Species	Number	Tagged
Walleye	16	15
Yellow Perch	3	3
Northern Pike	6	5
Shorthead Redhorse	3	0
White Sucker	25	0
Silver Redhorse	7	0
Rock Bass	3	3
Channel Catfish	5	5
Brown Bullhead	1	0
TOTAL	69	31

Gear : Large Trapnet
Date : 06/13/84
Station : 8L

Species	Number	Tagged
Walleye	1	0
White Sucker	3	0
Silver Redhorse	1	0
Channel Catfish	2	2
TOTAL	7	2

Gear : Large Trapnet
Date : 07/10/84
Station : 8L

Species	Number	Tagged
Walleye	106	102
Yellow Perch	1	1
Northern Pike	1	1
Shorthead Redhorse	4	0
White Sucker	7	0
Silver Redhorse	5	0
Rock Bass	2	2
Channel Catfish	10	10
Brown Bullhead	1	1
Carp	1	0
TOTAL	138	117

Gear : Large Trapnet
Date : 08/07/84
Station : 8L

Species	Number	Tagged
Walleye	6	6
Yellow Perch	2	2
Northern Pike	3	3
Shorthead Redhorse	1	0
White Sucker	6	0
Silver Redhorse	2	0
Rock Bass	2	2
Smallmouth Bass	4	4
Channel Catfish	1	1
TOTAL	27	18

Gear : Large Trapnet
Date : 09/18/84
Station : 8L

Species	Number	Tagged
Walleye	9	4
Yellow Perch	2	2
Shorthead Redhorse	1	0
White Sucker	7	0
Silver Redhorse	9	0
Rock Bass	3	3
Smallmouth Bass	2	2
Channel Catfish	7	5
TOTAL	40	16

205

ENVIRONMENTAL BASELINE STUDIES DURING 1984 OF LAKE NICOLET AND MUNUSCONG BAY, ST. MARYS RIVER, MICHIGAN, IN RELATION TO PROPOSED EXTENSION OF THE NAVIGATION SEASON

Charles R. Liston and Clarence D. McNabb
Principal Investigators
Department of Fisheries and Wildlife
Michigan State University
East Lansing, Michigan 48824-1222

PART II. EFFECTS OF COMMERCIAL SHIP-PASSAGE ON EMERGENT WETLANDS IN LAKE NICOLET AND ONE NON-WETLAND SITE OF THE ST. MARYS RIVER, 1984

by

Clarence D. McNabb, Ted R. Batterson, John R. Craig,
Paul Roettger, and Mehdi Siami

206

DISCLAIMER

The opinions, findings, conclusions, or recommendations expressed in this report/product are those of the authors and do not necessarily reflect the view of the Office of Biological Services, Fish and Wildlife Service, U.S. Department of the Interior, and the Corps of Engineers, U.S. Department of the Army, nor does mention of trade names of commercial products constitute endorsement or recommendation for use by the federal government.

TABLE OF CONTENTS

Page

PREFACE iv

EXECUTIVE SUMMARY v

LIST OF FIGURES vi

LIST OF TABLES ix

LIST OF ABBREVIATIONS, SYMBOLS, AND CONVERSIONS xi

ACKNOWLEDGMENTS xii

INTRODUCTION 1

MATERIALS AND METHODS 13

RESULTS 17

DISCUSSION 40

SUMMARY 71

LITERATURE CITED 73

PREFACE

Considerations of potential impacts from extended season commercial shipping in connecting waters of the Great Lakes have revealed that very little empirical data are available on physical disturbances along shorelines created by ship-passages. Although general changes in water movements as ships pass have been described qualitatively, quantitative measurements of change are lacking. Moreover, observations during winter have generally not been made at all.

Direct impacts from extended shipping season on the Great Lakes, if they occur, undoubtedly will be related to direct physical disturbances of water and ice caused by passing vessels in the narrow connecting waterways. In this study new techniques were developed for monitoring direct change caused by passing vessels at several nearshore sites in Lake Nicolet of the St. Marys River. Water current speed and direction, water level, wave heights, and the physical-chemical aspects of water were studied as 130 commercial ships passed. The data provide a beginning for understanding such effects, though only open-water data (summer) were taken, leaving critical seasons such as December - February (ice-on) and early spring (ice-off) unstudied. Biological phenomena associated with physical changes also are poorly known, although these will be most important to understand in relation to extended season shipping.

This report was submitted in fulfillment of contract number 14-16-009-84-029 by the Department of Fisheries and Wildlife, Michigan State University, under the sponsorship of the Office of Biological Services, U.S. Fish and Wildlife Service. Major funding was provided by the U.S. Army Corps of Engineers, Detroit District, with additional support from the U.S. Fish and Wildlife Service, Michigan State University, and the Michigan Agricultural Experiment Station.

The address of the information transfer specialist for this study is as follows:

Information Transfer Specialist
Office of Biological Services
U.S. Fish and Wildlife Service
Federal Building, Fort Snelling
Twin Cities, MN 55111

Charles R. Liston, Ph.D.
Associate Professor
Department of Fisheries & Wildlife
Michigan State University
East Lansing, MI 48824-1222

Clarence D. McNabb
Professor
Department of Fisheries & Wildlife
Michigan State University
East Lansing, MI 48824-1222

EXECUTIVE SUMMARY

Measurements were made between May and September 1984 for a number of variables in wetlands and one non-wetland site of the St. Marys River during the passage of cargo vessels plying that waterway. Changes in water level, current direction and velocity were measured for 130 ship-passage events. A predictable pattern of water movement occurred at those sites for many of those events. Results showed that in this pattern there was a reversal of flow between the drawdown phase and the surge phase of the water cycle. It was in these phases that maximum current velocities were measured. For most of the events these maxima occurred during drawdown, for others during surge. The greatest current velocities recorded were around 1.0 m sec^{-1}. The total change in water level within these sites ranged from 0.01 to 0.70 meters. The influence of vessel passage on wetlands varied considerably from site to site. It appears that a number of factors contribute to the change in water level and current velocities generated by ship-passage.

Work with traps sets at outer boundaries of wetlands with mature summertime vegetation showed that sediments tended to move primarily in the onshore and downriver directions during ship-passages that were selected for measurements. Sediments moved from the direction of wetlands as well, but at rates lower than those from other directions. Data collected during 19 drawdown-surge cycles on four sites did not show significant net exchange of suspended algae or other suspended or dissolved organic food materials (by weight) between wetlands and the river. Movement of water during these ship-passages tended to enrich the wetlands studied with dissolved residues (filtrate residue on evaporation). For nine ship-passages monitored at one site, concentrations of dissolved residues in drawdown water exiting the wetland was always less than concentrations in surge water re-entering the wetland. Sets of conditions that might explain this result are discussed.

LIST OF FIGURES

Figure		Page
1	Map of the Great Lakes system showing the location of the St. Marys River, the connecting waters of Lakes Superior and Huron.	2
2	Wetland sites of the St. Marys River monitored during commercial ship-passages for the open-water period of 1984. The orientation and location of the wetland face is represented by the dark line at the end of each arrow.	4
3	The non-wetland site, F, of the St. Marys River monitored during commercial ship-passages for the open-water period of 1984.	5
4	Transects for ice measurements in the emergent wetland on Site E (Study Site II in Liston et al. 1986) during winter of 1983. Shore is at the top of the figure, and north (upriver) is to the right.	7
5	Snow and ice cover along Transect A on Site E on January 18, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.	8
6	Snow and ice cover along Transect B on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.	9
7	Snow and ice cover along Transect C on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.	10
8	Snow and ice cover along Transect D on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.	11
9	Frequency distribution of vessel lengths for the 130 commercial ship-passages monitored during the open-water period of 1984 on the St. Marys River.	41
10	Frequency distribution of vessel beams for the 130 commercial ship-passages monitored during the open-water period of 1984 on the St. Marys River.	42

Figure		Page
11	Water level changes and current vectors generated by the upbound passage of the Ashley Lykes (Passage 10B-C of Table 4). Dashed vertical lines separate the phases of the water cycle.	44
12	Water level changes and currents vectors generated by the downbound passage of the Rimouski (Passage 3B-F of Table 5).	45
13	Water level changes and current vectors generated by the upbound passage of the Royalton (Passage 13C-C of Table 6).	46
14	Water level changes and current vectors generated by the upbound passage of the Burns Harbor (Passage 11C-F of Table 7).	47
15	Water level changes and current vectors generated by the upbound passage of the Str. Comeaudoc (Passage 5D-F of Table 8).	48
16	Water level changes and current vectors generated by the downbound passage of the Edward B. Greene (Passage 4E-C of Table 9).	49
17	Water level changes and current vectors generated by the downbound passage of the Royalton (Passage 2F of Table 10). For this non-wetland site the baseline for the current vectors is oriented parallel to the shoreline.	50
18A	Vessel length versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.	53
18B	Vessel length versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.	54
19A	Vessel beam versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.	55
19B	Vessel beam versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.	56

Figure		Page
20A	Vessel speed versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.	57
20B	Vessel speed versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.	58
21	Maximum change in stage height versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.	59
22A	Maximum change in stage height during drawdown for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.	61
22B	Maximum 10 second mean current velocity during drawdown for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.	62
23A	Maximum change in stage height during surge for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.	63
23B	Maximum 10 second mean current velocity during surge for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.	64
24	The relationship at Site C between differences in dissolved residues in water during drawdown and surge and changes in water level in the St. Marys River during ship-passage events of the open-water period of 1984.	70

LIST OF TABLES

Table		Page
1	Estimates of ash-free dry weight (AFDW) net productivity per square meter of plant community in the St. Marys River for the growing season of 1983: May 10 - October 15. All productivities are relative to phytoplankton (Liston et al. 1986).	1
2	Vegetational status of various wetland sites of the St. Marys River and predicted vessel passage effects.	6
3	Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site A of the St. Marys River during the open-water period of 1984.	18
4	Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site B of the St. Marys River during the open-water period of 1984.	20
5	Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site B of the St. Marys River during the open-water period of 1984.	22
6	Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site C of the St. Marys River during the open-water period of 1984.	24
7	Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site C of the St. Marys River during the open-water period of 1984.	26
8	Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site D of the St. Marys River during the open-water period of 1984.	28
9	Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site E of the St. Marys River during the open-water period of 1984.	30
10	Physical data observed during commercial ship-passages and associated disturbances in the near-shore waters at Site F of the St. Marys River during the open-water period of 1984.	32

Table		Page
11	Organic carbon and residue values for various ship-passage events at Sites B, C, D, and E of the St. Marys River during the open-water period of 1984.	34
12	Chlorophyll a and sediment accumulation values for various ship-passage events at Sites B, C, D, and E of the St. Marys River during the open-water period of 1984.	37
13	Frequencies of size class distribution for vessel length (in feet) for the 130 events monitored during the open-water period of 1984 on the St. Marys River.	40
14	Frequency distribution of vessel speed for the 130 ship-passage events monitored at various sites of the St. Marys River during the open-water period of 1984.	43
15	Distances from the sampling stations to the middle of the upbound and downbound navigational channels of the St. Marys River. For Sites A through E these distances were from the face of the wetland and perpendicular to it.	60
16	Vegetational status of selected wetland sites of the St. Marys River, predicted and maximum observed drawdown, and calculated areas of wetland exposed for those levels of drawdown.	65

LIST OF ABBREVIATIONS, SYMBOLS, AND CONVERSIONS

AFDW	Ash-free dry weight
°C	Celcius, degree
cm	Centimeter (0.3937 inches)
cm day^{-1}	Centimeters per day
DOC	Dissolved organic carbon
ft	Foot (feet)
g	Gram (0.035 ounces)
(g)	Gas
GF/F	Glass fiber filter
km	Kilometer (0.6214 mile)
km hr^{-1}	Kilometer per hour
l	Liter (0.264 gallon)
mi	Mile (1.609 km)
m	Meter (3.28 feet)
m sec^{-1}	Meters per second
mg l^{-1}	Milligrams per liter
mg/l	Milligrams per liter
mm	Millimeter (0.0394 inches)
mph	Miles per hour
nm	Nanometers
POC	Particulate organic carbon
TOC	Total organic carbon
ug l^{-1}	Micrograms per liter
<	Less than
>	Greater than
≤	Less than or equal to
≥	Greater than or equal to
%	Percent
'	Feet
"	Inches

ACKNOWLEDGMENTS

Mr. Gerald Haarer, Director of the Land Management Office, Michigan State University, is gratefully acknowledged for his help in securing off-campus work and living quarters at the MSU Dunbar Forest Experiment Station, Barbeau, Michigan. Much of this coordination and data analysis for this study was done at the Michigan State University Limnological Research Laboratory.

We thank Linda Roettger for her excellent, professional help in securing field data.

The valuable interest and encouragement shown by Rich Greenwood and T.J. Miller, U.S. Fish and Wildlife Service, East Lansing Field Office, was much appreciated. Similar interest as demonstrated by environmental protection officials of the Michigan Department of Natural Resources made us further aware of the importance in obtaining these particular data on ship-passage.

The campus space, administrative assistance, and facilities provided by Michigan State University, were also important for the completion of this report. Partial staff salaries for this project were provided by the Michigan Agricultural Experiment Station.

Mr. Keith Kraai, Ms. Doris Medly, Ms. Linda Boor, and Mr. William Aultfather, U.S. Fish and Wildlife Service, have been most understanding and helpful with contract administrative duties. Similarly, the many hours in contract administration given by Mr. Howard Grider, Mr. Gene Stauffer, and Ms. Pat Patton, Michigan State University Contracts and Grant Administration Department, are gratefully recognized. We also appreciate the adminstrative assistance, patience, and encouragement provided by Mr. Les Weigum, Dr. Jim Galloway, Mr. Don Williams, Mr. Tom Freitag, and Mr. Dan Thompson of the U.S. Army Corps of Engineers, Detroit District. Finally, the U.S. Army Corps of Engineers, Detroit District, is thanked for their overall interest displayed in this project and in providing major funding. Funding for report preparation was provided by the U.S. Fish and Wildlife Service, Michigan State University, and the Michigan Agricultural Experiment Station.

INTRODUCTION

The St. Marys River is the only outflow from Lake Superior to the other Great Lakes and serves as the major commercial shipping link between the northwestern United States and metropolitan areas of the lower Great Lakes (Figure 1). It flows about 120 km from its headwaters in Whitefish Bay to Lake Huron at Detour, Michigan. From its headwaters to Lake Huron the St. Marys River descends approximately 6.7 m. Most of this fall occurs at the rapids of Sault Sainte Marie. Navigation around the rapids is provided for by canals and locks on both the United States side and the Canadian side. Below these locks, the river is divided into several channels and shallow lakes, first by Sugar Island and subsequently by Neebish and St. Joseph Islands.

In February 1979, studies were begun by the Department of Fisheries and Wildlife, Michigan State University, under contract with the U.S. Fish and Wildlife Service, with funding provided by the U.S. Army Corps of Engineers, to determine baseline environmental conditions of the St. Marys River. Since that time a tremendous amount of data on this riverine system has been collected. The overall goal of the studies has been to provide both quantitative and qualitative limnological and biological information from the river for the assessment of environmental impacts from existing and proposed navigational programs. This present study was made to address the potential impacts of extension of the winter navigation season to 31 January ± 2 weeks.

Liston et al. (1986) have reported that the emergent wetlands are the most dominant component of the primary producers of this riverine community. On a relative basis, the emergent wetlands (where the emergent wetlands are defined as a complex of both vascular plants and their associated periphyton were over 230 times more productive than the phytoplankton and 30-60 times more productive than submersed plant stands (Table 1).

Table 1. Estimates of ash-free dry weight (AFDW) net productivity per square meter of plant community in the St. Marys River for the growing season of 1983: May 10 - October 15. All productivities are relative to phytoplankton (Liston et al. 1986).

Community Type	Relative AFDW Productivity
Phytoplankton	1
Submersed Plant Stands	
Charophytes	4
Quillwort	8
Mixed Stands[1]	4
Emergent Wetlands	
Vascular plants	234
Periphyton	2

---

[1] Principally charophytes and quillwort with occasional Potamogeton.

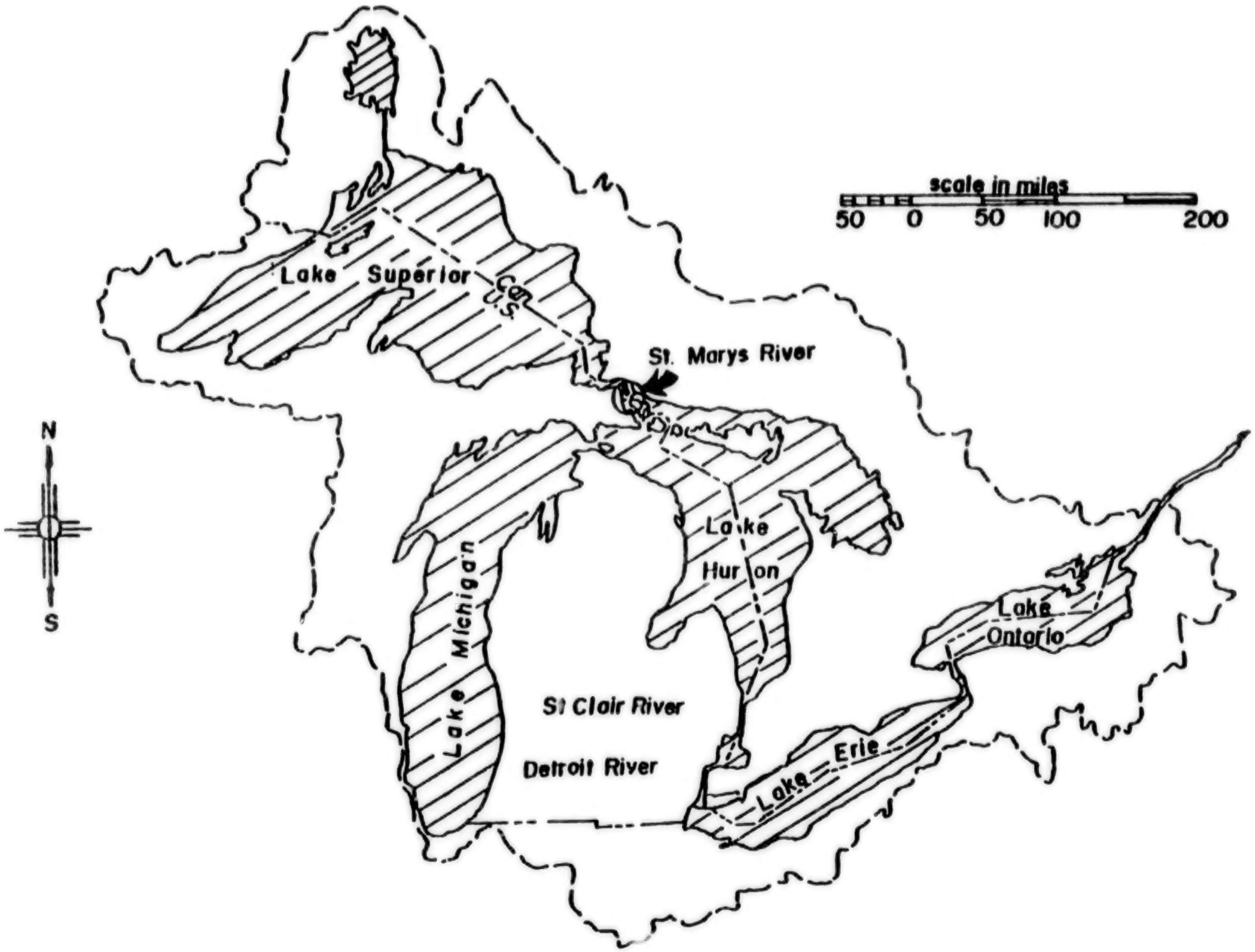

Figure 1. Map of the Great Lakes system showing the location of the St. Marys River, the connecting waters of Lakes Superior and Huron.

The occurrence of the major emergent wetlands in the St. Marys River system is along the protected edges of wide reaches of the river; narrow restricted channels have poorly developed fringes of emergent vegetation, or none at all.

Regions of wide expanse (e.g. - Lake Nicolet, Munuscong Lake, Lime Island) have shorelines variously exposed to waves and currents. Shores with the most exposure have no emergent vegetation; the bottom is rock or shifting sand. Where emergent wetlands do occur, two vegetation types appear to result from the degree of exposure:

(1) Least-protected sites - have *Scirpus americanus* (three-square bulrush) or *Eleocharis smallii* (spike rush) as the dominate vegetation types;

(2) Most-protected sites - have *Scirpus acutus* (hardstem bulrush) and *Sparganium eurycarpum* (bur reed) as the dominate vegetation types

Sediments in these wetlands are typically clay with variable fractions of organic detritus and sand.

Most-protected vegetation types occur in several sheltered locations on the east shore of the St. Marys River. Baie de Wasai and Shingle Bay in Lake Nicolet and the area of Hay Point in the Lime Island region are examples. The west shore of the river lies in the lee of prevailing winds and development of most-protected emergent wetlands is more pronounced there. The large tract of *Scirpus acutus* - *Sparganium eurycarpum* that extends from the Michigan State University Dunbar Forest Experiment Station northward 10-12 km is a good example of wetland development on a most-protected site. A portion of this site is described in detail in Liston et al. (1986) and is designated as Study Site II in that document.

Another large and important (from the standpoint of sediment stabilization and productivity) wetland is in a least-protected area, occurring on the windward (eastern) shore of Lake Nicolet between Nine Mile Point and Shingle Bay. Both this and the tract near the MSU Dunbar Forest Experiment Station are influenced by drawdown and surge due to ship-passage in adjacent navigation channels.

Wuebben (1983) has addressed the effects on shoreline areas of the St. Marys River expected from passage of the largest ships now traveling the Great Lakes waterways (305 m length, 32 m beam, with a maximum draft of 7.8 m). A principle effect of these, and vessels of smaller size, is a creation of a water cycle in which there is drawdown along adjacent shorelines as ships pass and the subsequent resurgence of water back into the drawdown area.

Table 2 shows the categorization of various wetland sites of the St. Marys River (see Figures 2 and 3 for their locations) and estimates of drawdown that would occur if a 305 m ship moving at the existing speed limit passed those sites. The estimates of drawdown are from Wuebben (1983) and the categorization based on interpretation of oblique aerial photographs taken during November 1983 and our earlier work on those wetlands (Liston et al. 1986).

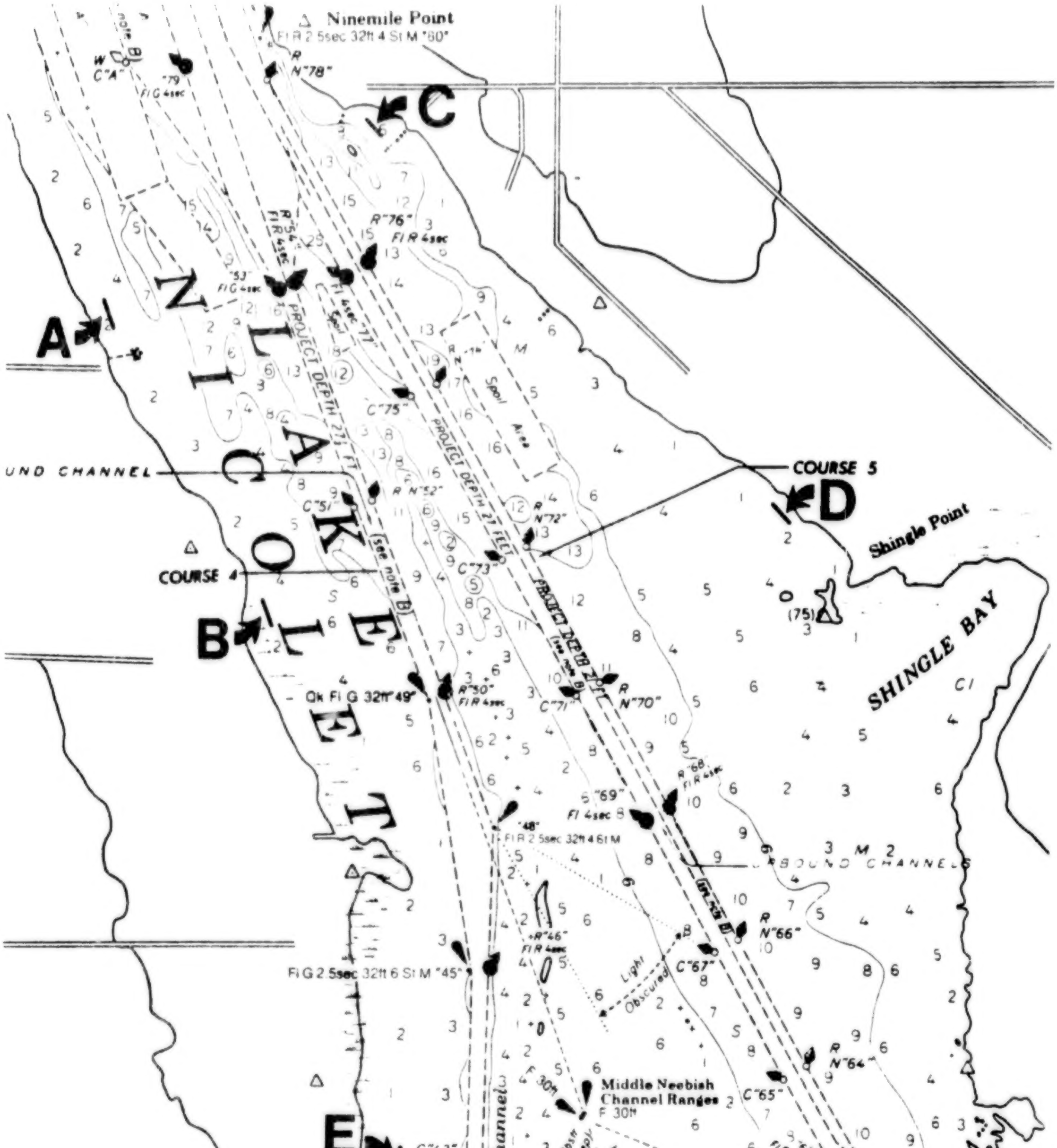

Figure 2. Wetland sites of the St. Marys River monitored during commercial ship-passages for the open-water period of 1984. The orientation and location of the wetland face is represented by the dark line at the end of each arrow.

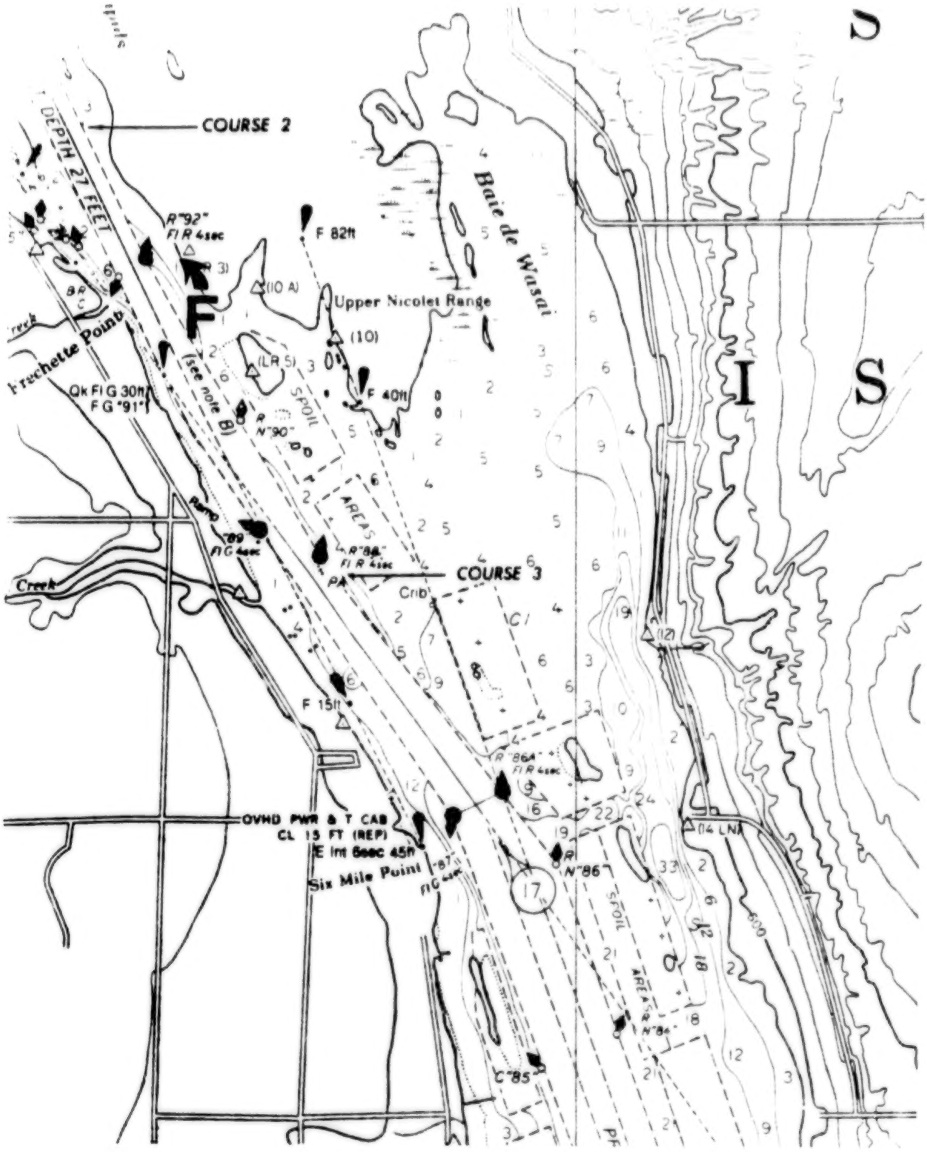

Figure 3. The non-wetland site, F, of the St. Marys River monitored during commercial ship-passages for the open-water period of 1984.

Table 2. Vegetational status of various wetland sites of the St. Marys River and predicted vessel-passage effects.

Site	Vegetation Type	Vegetation Pattern	Predicted Drawdown (m)
A	Most-Protected	Undisturbed	0.06
B	Most-Protected	Disturbed	0.39
C	Least-Protected	Disturbed	0.29
D	Least-Protected	Undisturbed	0.20
E[1]	Most-Protected	Disturbed	0.49
F	None	-	0.30

[1] This site was designated Study Site II in Liston et al. (1986).

Work that is reported here is for the effects of drawdown and surge on selected sites during the open-water period of 1984. However, it is important to remember that our principle concern is with the effects of ship-induced movement of water and ice on the biological resources of wetlands of this system during ice-on periods, because we know that for some years, ice-on in the wetlands is in progress during the interval 31 January ± 2 weeks.

Data on the ice-on process was obtained by measuring ice thickness along transects on the emergent wetland of Site E from December 1982 to mid-February 1983 (Liston et al. 1986). These data suggest the kind of damage that could occur to overwintering rootstocks, the perennating organs of wetland plants, if ship-passage promotes ice movement during ice-on periods. To illustrate the growth of an ice sheet, borings were made along transects running across the wetland of Site E from shore toward the adjacent navigation channel. Positions of these transects are shown in Figure 4. Thickness of layers of snow, ice, and water were measured, and depth from the surface of ice to sediments was recorded.

A thin ice sheet was present on the wetland in late December 1982 and early January of 1983. It grew gradually thicker until it reached a depth of approximately 60 cm in outer portions of the wetland in mid-February. As the ice sheet grew thicker, it reached down 15-30 cm into wetland sediments in the shoreward 200-250 m of the wetland. Since 80-90% of wetland rootstock biomass is in this surface layer of sediments (Liston et al. 1986), rootstocks became encapsulated in the ice sheet as it grew. Systems of cracks were observed in the ice sheet during this work. Open water in cracks, typical of hinges between anchored shorezone ice and floating ice moving with waves and currents, were never observed on the wetland. Hinges have been reported to occur on other sites on the river (Kraii personal communication).

An intermediate condition of growth of this ice sheet is shown in Figures 5 through 8. These figures were generated from data collected in mid-January 1983. They illustrate ice conditions that can occur on emergent wetlands during the period proposed for extending the navigation season to

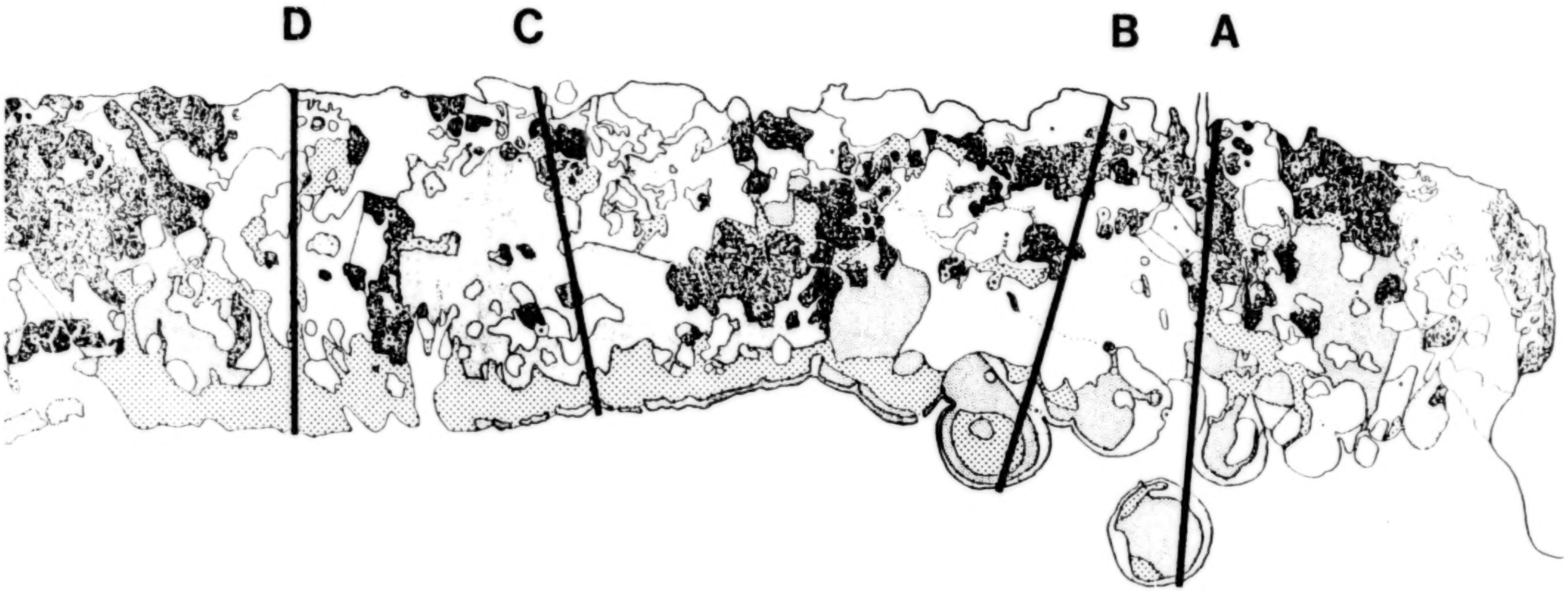

Figure 4. Transects for ice measurements in the emergent wetland on Site E (Study Site II in Liston et al. 1986) during winter of 1983. Shore is at the top of the figure, and north (upriver) is to the right.

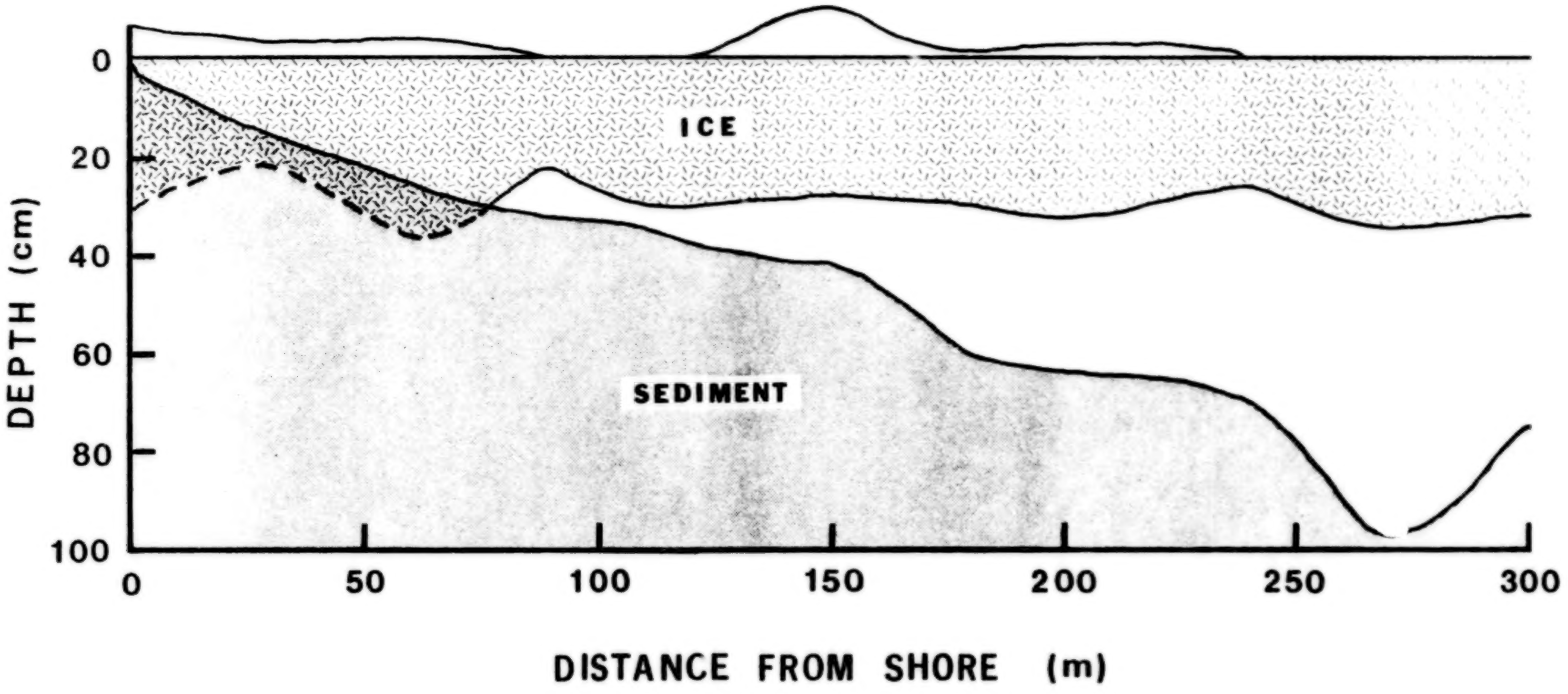

Figure 5. Snow and ice cover along Transect A on Site E on January 18, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.

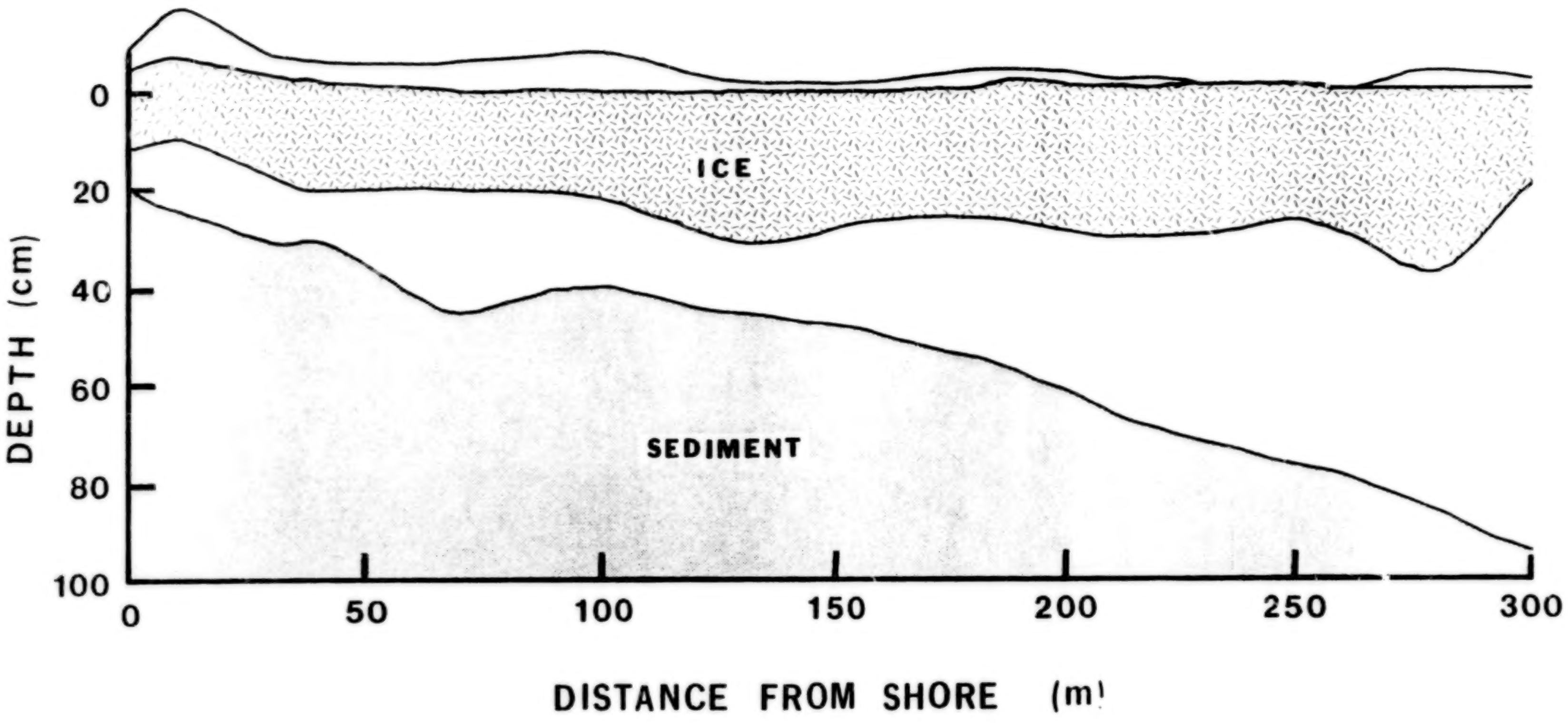

Figure 6. Snow and ice cover along Transect B on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.

226

BLANK PAGE

BLANK PAGE

BLANK PAGE

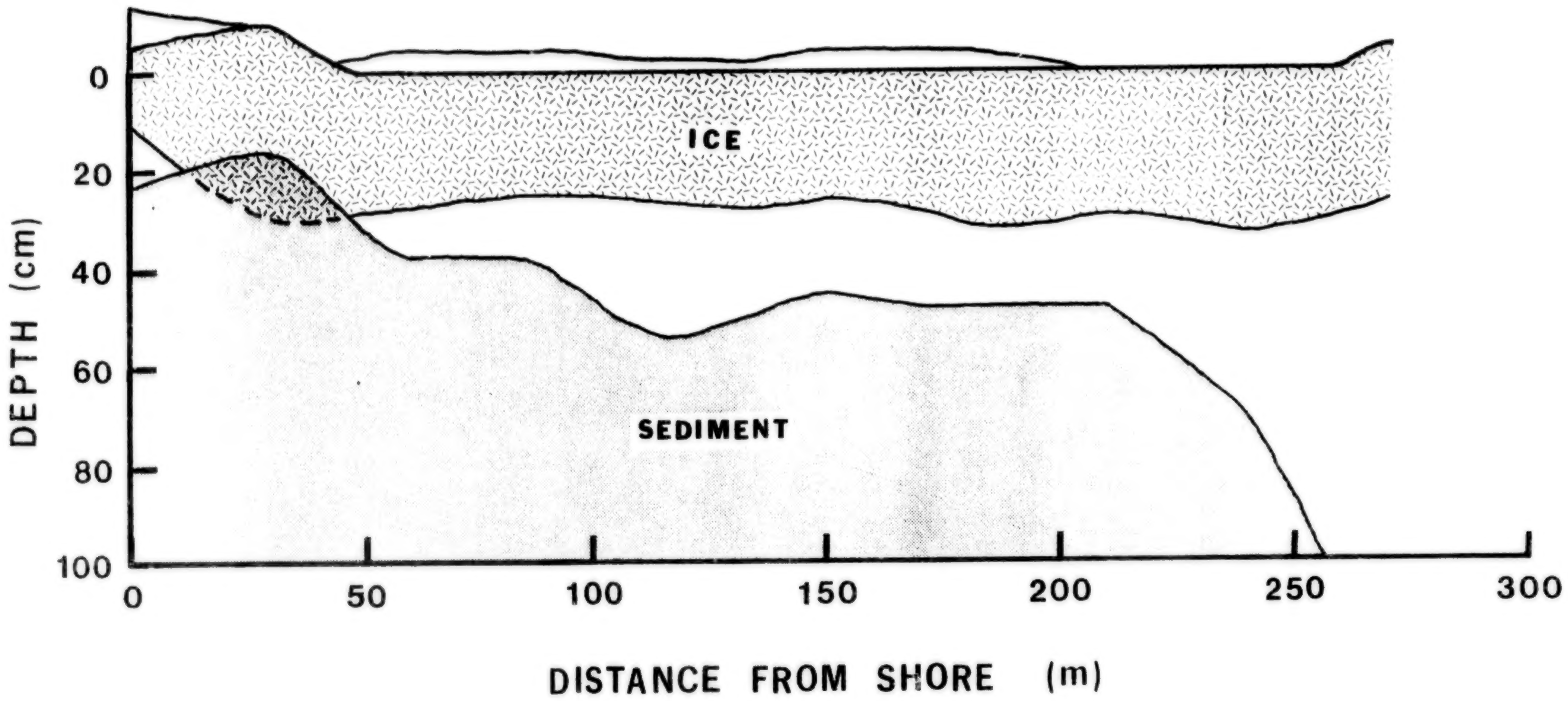

Figure 7. Snow and ice cover along Transect C on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.

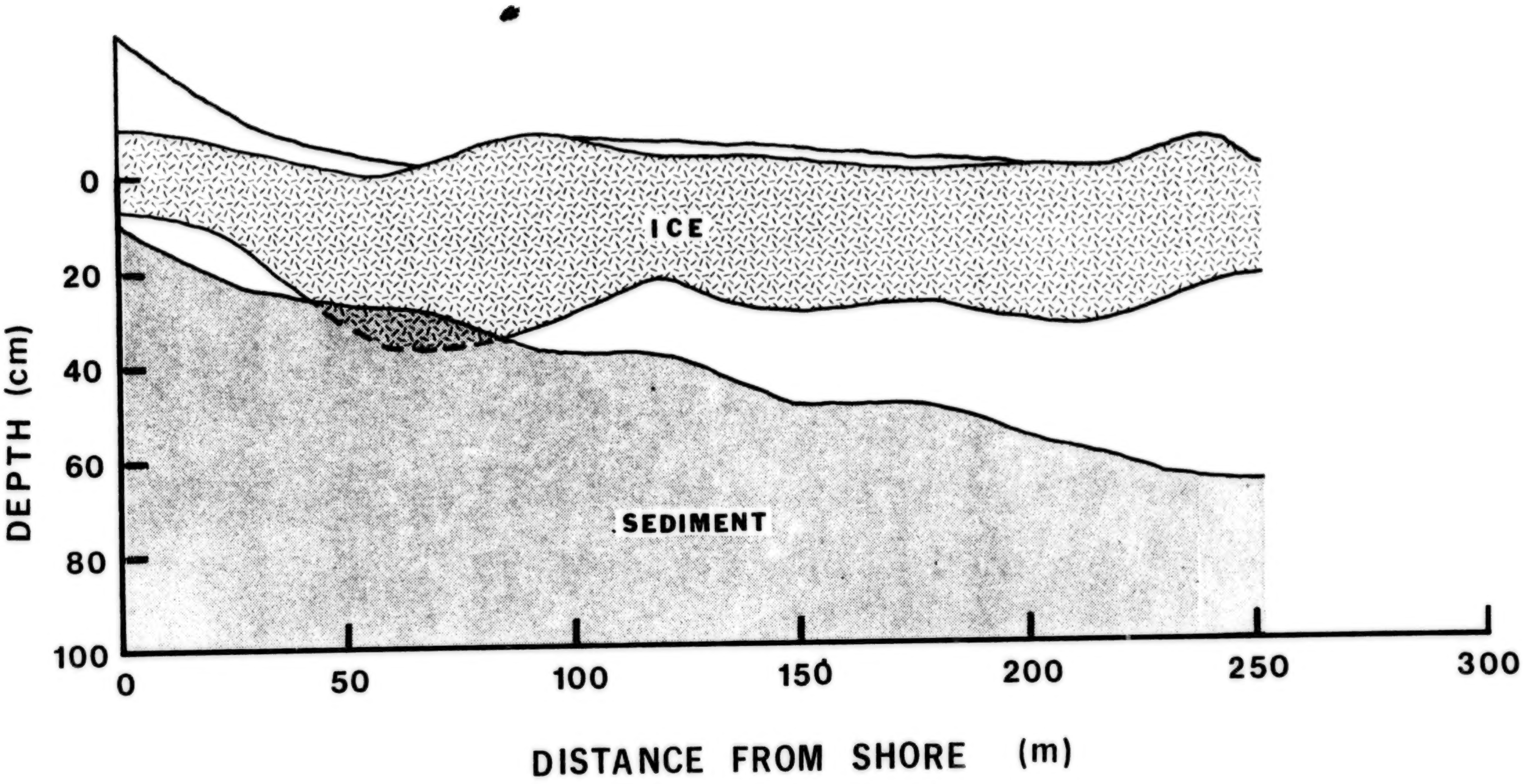

Figure 8. Snow and ice cover along Transect D on Site E on January 19, 1983. Conditions shown are from the shore to the outer edge of the emergent wetland. Thickness of snow is shown above the ice: water is shown between ice and sediments.

31 January ± 2 weeks. From these figures that represent a stage in growth of the ice sheet, extension backward in time to minimum development (December) and forward to maximum ice sheet development (mid-February) can be visualized.

It is clear from data in Figures 5 through 8 that junctions between frozen sediments and water over wetland sediments will occur and will tend to move gradually offshore as the ice sheet thickens from late-December to mid-February. If hinges do not occur in the ice sheet, vertical movement of the sheet due to waves moving onshore from channel areas will provide force to uplift and detach plant rootstocks from sediments at junctions between frozen sediments and water. Wind driven waves are likely to cause such disruption in shallow portions of wetlands during early ice sheet formation when open water exists in offshore portions of the river. Offshore portions of the river were frozen in 1983 when the wetland ice sheet reached intermediate development as shown in the figures. Because wind driven waves would not normally occur 31 January ± 2 weeks, water movements like those measured during ship-passage in this study would be the sole cause of disruptive uplift forces during the time of late ice sheet development and the remainder of the winter period.

Maps from previous work (Liston et al. 1986) show that open areas in the emergent vegetation community commonly occur in shallow mid-portions of these wetlands. We hypothesize that one of the agents causing disruption of vegetation and open areas is ice movement due to natural causes or passages of ice-breakers or commercial ships during the ice-on (ice-off) process. Large fluctuations in mean water water level of the river between years may play a role as well. It should be noted that rootstocks along outward faces of wetlands in 1.0-1.5 meters of water escape whatever disturbances ice movement might cause because of their depth and the thickness of the ice sheet (ca. 60 cm), and these rootstocks tend to put up shoots in the growing season that form regular wetland boundaries.

For 1984 we measured ship-passage effects during the open-water period in selected portions of least-protected wetland tracts that occur on the windward shore of Lake Nicolet between Nine Mile Point and Shingle Bay, and the most-protected tracts that occur on the west shore of this lake (an additional site was selected near Frechette Point where there was no established wetland). From these measurements, predictions can be made regarding which wetlands in Lake Nicolet will be least susceptible to ice movement caused by shipping during 31 January ± 2 weeks.

MATERIALS AND METHODS

Six sites were selected for study and are listed in Table 2. Figure 2 shows the location of Sites A through E. Sampling stations for these sites were located at either the face of the wetland, the boundary between the emergent plants and the open-water portion of the river, or at an area of channelization through the wetland. Two stations were established at Sites B and C, one at the face and the other at the opening of an area of channelization. The other three sites had only one sampling station. Sites A and D had stations located at the wetland face and Site E at the opening of an area of channelization. Stations are identified in the text by a site designation followed by the letter "F" for wetland face or "C" for an area of channelization. Site F was the only site without a wetland. The sampling station was located approximately 5 m from the shore of Sugar Island (see Figure 3 for its location). Bathymetric maps for each of these sites were generated from field data collected in the spring.

At each station for each ship-passage event, current velocity, current direction, change in water level, wind direction and velocity, and wave amplitude were measured. A pontoon boat which was securely moored served as a sampling and recording platform. As an event occurred, a stopwatch was used to synchronize the records of three observers: those recording current velocity, current direction and change in water level. Measurements were started at time zero and successive 10 second intervals were announced audibly to provide synchrony in the records.

Water current velocities during vessel passages were measured 0.20 m from the sediment surface with a Teledyne Gurley Model 645 pygmy current meter with digital display. The velocity range of the meter is 0.01 to 7 m sec^{-1} with a resolution of 0.01 m sec^{-1}. The digitized display updated current velocities every 1.4 seconds and 7 readouts were recorded for each 10 second interval. These were averaged to obtain an overall mean current velocity for an interval.

The direction of water movements during vessel-passages were ascertained from observations of the orientation of a light-weight Plexiglas vane. The vane, constructed of 3 mm thick Plexiglas was 14 cm long and 12 cm high, was set in the sediments so that the center was 0.2 m above the sediment surface. The rod stood vertically and pivoted on a free-moving pin at its base. It was guided in the vertical direction by passing through a hole in a recording table that stood at top the assembly 40-60 cm above the water surface. A circular protractor was set on the recording table and was oriented in relation to magnetic north. A pointer was mounted on the top of the rod in line with the vane and rotated above the compass showing the angle from which currents passed over the site. At the end of each 10 second interval, in synchrony with current velocities and stage height recordings, the angle of the pointer was recorded.

Preliminary testing indicated that the current direction indicator responded to water currents above the threshold sensitivity of the current meter (0.01 m sec^{-1}). It took from 1-3 seconds for the indicator to change directions. Using the instrument during times of no-passage when wind-blown waves moved on sampling sites showed that the vane tended to orient at a right angle to the path of propagation of waves. This was an expected result: as deep-water surface waves move on-shore their cycloid motions tend to be transformed into a back and forth movement that extends to the bottom and has an axis parallel to the direction of propagation (Wetzel 1983).

A Leupold & Stevens Type F water level recorder was used to record changes in river stage heights at the sites during ship-passage events. The water level recorder was outfitted with a 1:2 gage scale (0.6 m water level change for one revolution of the chart drum, where the smallest vertical chart division equals 0.4 cm and a 146.3 cm day^{-1} time scale. This corresponds to the pen traveling the entire width of the chart in 4 hours, where the smallest horizontal chart division is equal to 2.5 minutes. A 25 cm diameter by 50 cm length of stove pipe mounted on a rod was pushed into the sediments and served as the stilling well for the 20.3 cm diameter float of the stage height recorder. It was open so that water within the well responded to surface elevation changes. The well minimized the extent of excursion of the pen of the recorder due to wave action. Stage height was recorded at 10 second intervals with the pen of the recorder being moved horizontally by hand at the end of each time interval. Stage height for an interval was taken as the mid-point of the vertical trace of the pen made during each interval. The total change in water level was calculated by adding the absolute value of the maximum negative change in stage height to the maximum positive change in stage height. Baseline (or zero-point) stage heights were recorded by allowing a spring wound clock to drive the recorder for at least 5 minutes prior to ship-passage.

The average wind velocity during a vessel passage was monitored with a Weathertronics Model 2511 totalizing cup anemometer. The instrument has a resolution of 0.1 km with a starting speed of 1.6 to 3.2 km hr^{-1}. Average wind velocity was calculated by dividing the total kilometers accumulated by the time of duration of the event and expressed as km hr^{-1}. Wind direction was determined by observation of a plastic streamer. Wind generated wave amplitude was determined by observations of wave crests and troughs against a water level staff gauge. The amplitude was calculated as the difference of the average of ten values for wave crests and troughs.

In addition to the above data for each ship-passage event, the name, length, beam, amid-ships draft, and over the ground speed were recorded. The length that was recorded is defined as the distance from the vessels forwardmost and aftermost extensions, while beam is the dimension of its greatest width as measured over the frames. These two values were taken from tables presented in Greenwood and Dills (1984). A stopwatch was used to obtain the time required for each ship to pass some fixed point. This value and the length were used to calculate the ship's speed.

For selected ship-passage events water samples were collected for determination of organic carbon, residues, and chlorophyll a. A 12-volt submersible pump was positioned 20 cm above the sediment surface delivering water to 1 l sample bottles at 10 second intervals that coincided with intervals for stage height and current measurements. Five composite samples were generated from these 1 l samples. The volume of each aliquot contributing to a composite sample was determined on a current velocity or volume proportional basis. The resulting 4 l composite samples represented water quality during the 5 phases observed in a ship-passage cycle: (1) initial, (2) standing wave, (3) drawdown, (4) surge, and (5) post-passage. The composite water samples were stored in the dark at 4^{o}C and transported from the field to the MSU Dunbar Forest Experiment Station where filtration and initiation of analyses began within 6 hours of collection.

Total organic carbon (TOC) and dissolved organic carbon (DOC) were determined using a Beckman Model 915-A Carbon Analyzer (Van Hall and Stenger 1967). Organic carbon is converted to $CO_{2(g)}$ by injection of a micro-sample into a tube furnace packed with cobalt oxide impregnated asbestos at 950°C and the evolved $CO_{2(g)}$ determined by a non-dispersive infrared analyzer. Inorganic carbon was removed from the samples prior to organic carbon determination by the addition of concentrated hydrochloric acid and sparging with $N_{2(g)}$. Standards were prepared from primary standard grade anhydrous potassium acid phthalate (potassium biphthalate), $KHC_8H_4O_4$. DOC samples were prepared by filtration of the sample through a Whatman GF/F glass microfiber filter (effective retention size: 0.7 micrometer) prior to injection. Particulate organic carbon (POC) was calculated as the difference between TOC and DOC determinations.

Total and dissolved (filterable) residues were dried at 103 to 105°C and determined gravimetrically (USEPA 1979; APHA 1981). Samples were prepared for dissolved (filterable) residue determination by passage through a Whatman GF/F glass microfiber filter. Particulate (non-filterable) residues were calculated as the difference between total residue and dissolved (filterable) residue. Sediment trap accumulations were also determined gravimetrically after drying to constant weight at 103 to 105°C.

Chlorophyll pigments were extracted with 90% alkaline aqueous acetone and measured quantitatively by a sensitive fluorometric procedure (Yentsch and Menzel 1963; Lorenzen 1966; Strickland and Parsons 1972). This method allows for the differentiation between chlorophyll a, the only chlorophyll pigment which is present in all plant groups, and phaeopigments, its major degradation product which is physiologically inactive. Sample aliquots of no less than 1 l were filtered by vacuum through 47 mm diameter Whatman GF/F glass microfiber filters using a pressure differential of less than 0.5 atmospheres. The filters and retained materials were stored in aluminum foil envelopes at -10°C. These samples were transported in their frozen state to the Limnological Research Laboratory on the campus of Michigan State University where they were analyzed. The filter and retained materials were macerated in a stainless steel Douce tissue grinder with a few milliliters of reagent grade acetone. Particles of the filter were removed by centrifugation. Chlorophyll a was determined in 90% alkaline aqueous acetone solution using a Turner Model 111 Fluorometer with a Corning CS 5-60 primary filter, Corning CS 2-64 secondary filter, an F.4T4-BL blue source lamp, and a high sensitivity sample holder (Baker 1983). The fluorometer system was standardized by using a number of dilutions of a pure chlorophyll a stock solution of known concentration. The stock solution was prepared from commercially available pure chlorophyll a (Sigma Chemical Company). The concentration of the chlorophyll a stock solution was determined by using a Varian SuperScan 3 UV-Visible Spectrophotometer with a 2 nm bandpass and the trichromatic equations for chlorophyll a of Strickland and Parsons (1972).

Sediment traps were manufactured by the Division of Engineering Research Machine Shop, College of Engineering, Michigan State University. They were constructed from 6 mm thick clear Plexiglas and had a rectangular polyhedron configuration. The base plate was 17.8 cm long and 11.6 cm wide and affixed to it were two side walls (14.0 cm long) and one end-plate. All of these pieces were slotted and grooved. The grooved slots allowed for the insertion of two other Plexiglas plates which served as top and end closures. The enclosed space was 12.2 mm long, 10.4 mm wide, and 5.1 mm high. These closures facilitated placement and retrieval of the traps without loss or addition of sedimentary materials. After the traps were placed on the sediment surface, closure plates were removed, exposing one end and the top to sediment loading. Before retrieving the traps, the plates were replaced to enclose any accumulated materials. Two sets of four traps were required for each vessel-passage event in which sediment loading was determined. One set was used to measure ambient conditions while the other set was for measuring the effect of the vessel-passage itself. Each set was positioned such that the open end of the trap was oriented in one of four directions: upstream and parallel to the interface of the wetland and open-water portions of the river, downstream and parallel to the interface, channelward and perpendicular to the interface, and shoreward and perpendicular to the interface. The set of traps for the vessel-passage were left open for the duration of an event. The ambient set of traps were left open for an equivalent time interval during a period of no ship-passage. Net dry weight of sediments trapped during passage was calculated by subtracting ambient accumulation from passage accumulation.

RESULTS

Physical data for 130 ship-passage events monitored at different sampling stations during the open-water period of 1984 are presented in Tables 3 through 10. Each table consists of two pages. The first page contains data on the vessel being monitored, its direction of travel, its size and draft, and the speed at which it was moving on the river. Background wind and water levels and three columns of summary data on the effects of the influence resulting from ship-passage are also included on this page. Definitions for abbreviations used in the tables are presented at the bottom of the first page of Table 3

The second page contains data for four of the five different phases of the water cycle that is generated by vessel-passage. These are: initial, standing wave, drawdown, and surge. The values recorded for changes in water level were maxima for each of those phases. Data in the columns for maximum instantaneous velocity represent the maximum of the seven current velocity values that were recorded for any of the 10 second intervals for that particular phase of the water cycle.

Events that are labeled non-significant (NSE) are defined as those in which one or more of the following criteria were met during a ship-passage:

(1) no change in current direction,

(2) total change in stage height of less than 2 cm,

(3) no velocities greater than 0.02 m sec^{-1}.

Typically, for a non-significant event, all of the above criteria were met. A non-typical event (NT) was one in which there were no discernible water movement patterns as a vessel passed the site.

Water chemistry data and sediment accumulation for selected events at Sites B, C, D, and E are presented in Tables 11 and 12. Data for various forms of organic carbon and residues is presented in Table 11; chlorophyll in Table 12.

Sediment accumulation collected in the two sets of four traps is presented in Table 12. The net sediment accumulation was calculated as the difference between traps of the same orientation for the passage and non-passage (ambient) settings.

A few negative values appear in Tables 11 and 12 for particulate organic carbon and net accumulation of sediments, parameters which are derived by calculation. The magnitude of the values is small and it is most likely that they are the result of analytical error.

Table 3. Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site A of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction ($km\ hr^{-1}$)	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Phase of Occurrence
1A-F	St. Clair	6/19	1130	DB	770'00"	92'00"	27.0'	9.0	22.9 NW	15	150	2.4	0.03	SW
2A-F	Maplecliffe Hall	6/19	1430	UB	730'00"	75'00"	16.0	6.9	22.9 NW	15	150	3.2	0.03	
3A-F	Beavercliffe Hall	6/19	1630	DB	730'00"	75'00"	26.0'	9.5	22.9 NW	15	150	3.6	n.d.	
4A-F	John G. Munson	6/20	1220	DB	768'3"	72'00"	27.0'	9.7	5.0 SE	0	157	2.0	0.00	
5A-F	Edgar B. Speer	6/20	1300	UB	1004'00"	105'00"	20.5'	11.5	5.0 SE	0	157	10.1	0.11	DD
6A-F	Belle River	6/20	1315	UB	1000'00"	105'00"	19.0'	7.7	5.0 SE	0	157	10.1	0.09	SG
7A-F	Phillip R. Clarke	6/20	1355	UB	767'00"	70'00"	17.0'	9.8	5.0 SE	0	157	3.0	0.00	
8A-F	Canadian Navigator	6/20	1414	DB	729'10"	75'9.5"	25.6'	8.9	5.0 SE	0	157	<2.0	0.00	
9A-F	J. N. McWatters	6/20	1527	DB	730'00"	75'00"	26.0'	9.7	5.0 SE	2	157	<2.0	0.00	
10A-F	Montcliffe Hall	6/21	1125	DB	730'00"	75'9"	26.0'	10.0	Calm	0	154	<2.0	0.00	
11A-F	James R. Barker	6/21	1322	DB	1004'00"	105'00"	27.0'	9.6	Calm	0	154	6.5	0.02	
12A-F	V. W. Scully	6/21	1337	UB	730'00"	75'00"	16.0'	7.7	Calm	0	154	6.0	0.06	
13A-F	Canadian Progress	6/21	1525	UB	730'00"	75'00"	17.0'	10.7	6.0 SE	2	154	2.2	0.02	
14A-F	Cedarglen	6/21	1530	DB	603'9"	60'00"	26.0'	9.2	6.0 SE	2	154	<2.0	0.00	
15A-F	American Mariner	6/21	1545	UB	730'00"	78'00"	17.0'	10.8	6.0 SE	2	154	2.7	0.01	
16A-F	Indiana Harbor	6/21	1730	UB	1000'00"	105'00"	27.0'	8.5	6.0 SE	2	154	2.3	0.00	
17A-F	Yankcanuck	6/21	1750	DB	325'00"	49'00"	19.0'	8.6	6.0 SE	2	154	<2.0	0.00	
18A-F	Kingdoc	6/21	1800	DB	315'00"	49'00"	22.0'	8.9	6.0 SE	2	154	<2.0	0.00	
19A-F	Edward B. Greene	6/21	1820	DB	767'00"	70'00"	27.0'	10.1	6.0 SE	2	154	2.0	0.00	
20A-F	Menihek Lake	6/21	1906	DB	715'3"	75'3"	26.0'	9.1	6.0 SE	2	154	<2.0	0.00	

DB = downbound; UB = upbound; SW = standing wave phase; DD = drawdown phase; SG = surge phase; NSE = non-significant event; NT = non-typical event; n.d. = no data.

Table 3 (Continued).

Passage I.D.	Initial	Standing Wave			Drawdown			Surge		
	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1A-F	0.00	+1.2	0.05	0.03	-1.2	0.04	0.02	+1.0	0.03	0.02
2A-F	NSE									
3A-F	NSE									
4A-F	NSE									
5A-F	0.00	+2.5	0.00	0.00	-6.3	0.15	0.11	+3.8	0.09	0.08
6A-F	0.00	+3.8	0.05	0.03	-6.3	0.09	0.07	+1.2	0.11	0.09
7A-F	NSE									
8A-F	NSE									
9A-F	NSE									
10A-F	NSE									
11A-F	NSE									
12A-F	NSE									
13A-F	NSE									
14A-F	NSE									
15A-F	NSE									
16A-F	NSE									
17A-F	NSE									
18A-F	NSE									
19A-F	NSE									
20A-F	NSE									

Table 4. Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site B of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction ($km\ hr^{-1}$)	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Phase of Occurrence
1B-C	Frontenac	5/28	1340	UB	729'7"	75'3"	22.5'	11.0	Calm	3	80	17.4	0.22	SG
2B-C	Yankcanuck	5/28	1430	UB	325'00"	49'00"	11.0'	12.5	0.0	0	80	4.9	0.03	DD
3B-C	Edward B. Greene	5/28	1515	UB	767'00"	70'00"	17.5'	11.6	0.0	0	80	10.6	0.18	SG
4B-C	Elton Hoyt 2nd	5/28	1550	DB	698'00"	70'00"	27.0'	9.7	0.0	0	80	5.5	0.04	DD
5B-C	Black Bay	7/29	1119	DB	730'00"	75'00"	26.0'	8.2	5.5 SW	2	140	2.2	0.05	DD
6B-C	Edwin H. Gott	7/29	1220	UB	1004'00"	105'00"	19.0'	9.4	6.8 SW	2	140	12.0	0.09	DD
7B-C	Canadoc	7/29	1556	DB	604'9"	62'00"	24.0'	10.0	3.6 SW	2	140	2.0	0.03	DD
8B-C	Frontenac	7/29	1752	DB	729'7"	75'3"	26.0'	8.9	n.d.	2	140	2.4	0.06	DD
9B-C	Algolake	7/30	1432	UB	730'00"	75'00"	18.0'	10.2	8.7 E	n.d.	140	7.6	0.08	DD
10B-C	Ashley Lykes	7/30	1522	UB	593'00"	69'00"	15.0'	9.1	9.8 E	n.d.	140	17.9	0.20	DD
11B-C	A. S. Glossbrenner	7/30	1549	DB	730'00"	75'00"	26.0'	9.3	9.8 E	n.d.	140	4.9	0.04	DD
12B-C	Lewis Wilson Foy	7/30	1605	UB	1000'00"	105'00"	18.0'	10.3	9.4 E	n.d.	140	8.9	0.06	DD
13B-C	World Goodwill	8/1	1146	UB	520'00"	68'00"	18.4'	10.4	1.8 E	n.d.	n.d.	4.6	0.02	DD
14B-C	Beavercliffe Hall	8/1	1205	UB	730'00"	75'00"	16.0'	11.8	3.6 E	n.d.	n.d.	7.4	0.05	DD
15B-C	Paul Thayer	8/1	1227	UB	630'00"	68'00"	17.0'	8.3	2.0 E	n.d.	n.d.	9.7	0.08	DD
16B-C	Belle River	8/1	1250	UB	1000'00"	105'00"	18.0'	11.4	4.6 E	n.d.	n.d.	10.9	0.07	DD

Table 4 (Continued).

	Initial	Standing Wave			Drawdown			Surge		
Passage I.D.	Mean Velocity (m $\sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m $\sec^{-1}$)	Maximum 10 Sec Mean Velocity (m $\sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m $\sec^{-1}$)	Maximum 10 Sec Mean Velocity (m $\sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m $\sec^{-1}$)	Maximum 10 Sec. Mean Velocity (m $\sec^{-1}$)
1B-C	0.00	+3.4	0.04	0.03	-14.0	0.12	0.09	-2.0	0.36	0.22
2B-C	0.00	+2.9	0.00	0.00	-2.0	0.04	0.03	-0.7	0.00	0.00
3B-C	0.00	+3.3	0.05	0.04	-7.3	0.12	0.10	-0.8	0.22	0.18
4B-C	0.00	+2.3	0.06	0.04	-3.2	0.05	0.04	+0.4	0.00	0.00
5B-C	0.00	+1.0	0.00	0.00	-1.2	0.06	0.05	+0.1	0.00	0.00
6B-C	0.00	+3.6	0.02	0.01	-8.4	0.13	0.09	+2.2	0.05	0.04
7B-C	0.00	+0.2	0.00	0.00	-1.8	0.05	0.03	0.0	0.01	0.00
8B-C	0.00	+0.4	0.04	0.03	-2.0	0.07	0.06	0.0	0.00	0.00
9B-C	0.00	+2.2	0.00	0.00	-5.4	0.09	0.08	+1.6	0.00	0.00
10B-C	0.00	+5.5	0.08	0.07	-12.4	0.22	0.20	+1.8	0.08	0.05
11B-C	0.00	+1.1	0.02	0.02	-3.8	0.05	0.04	+0.8	0.04	0.03
12B-C	0.00	+4.0	0.04	0.03	-4.9	0.08	0.06	+2.5	0.07	0.05
13B-C	0.00	+2.6	0.00	0.00	-2.0	0.03	0.02	+0.6	0.00	0.00
14B-C	0.00	+1.0	0.02	0.01	-6.4	0.07	0.05	+0.8	0.05	0.03
15B-C	0.00	+2.8	0.02	0.01	-6.9	0.10	0.08	+0.4	0.10	0.07
16B-C	0.00	+3.6	0.03	0.02	-7.3	0.08	0.07	+2.8	0.02	0.02

Table 5. Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site B of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction (km hr^{-1})	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity (m sec^{-1})	Phase of Occurrence
1B-F	Algoport	8/30	1015	DB	658'00"	75'00"	22.0'	9.4	12.0 NW	9	130	2.4	0.07	DD
2B-F	Edgar B. Speer	8/30	1215	UB	1004'00"	105'00"	22.0'	10.0	14.5 NW	11	130	7.4	0.04	DD
3B-F	Rimouski	8/30	1443	UB	730'00"	75'00"	16.0'	11.5	16.8 NW	9	130	12.8	0.15	SG
4B-F	Black Bay	8/30	1532	DB	730'00"	75'00"	21.0'	10.1	16.4 NW	9	130	4.6	0.11	DD
5B-F	Mesabi Miner	8/30	1605	UB	1004'00"	105'00"	21.0'	9.4	15.2 NW	9	130	3.3	0.03	DD, SG
6B-F	Canadian Enterprise	8/30	1713	UB	730'00"	75'10"	17.7'	10.9	16.9 NW	9	130	5.7	0.04	SG
7B-F	Sable	8/30	1815	UB	594'3"	75'2"	12.0'	13.7	14.4 NW	9	130	11.5	0.10	SG
8B-F	J. N. McWatters	8/30	1938	DB	730'00"	75'00"	26.0'	9.9	9.3 NW	9	130	4.0	0.11	DD

Table 5 (Continued).

Passage I.D.	Initial	Standing Wave			Drawdown			Surge		
	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1B-F	0.00	+1.0	0.00	0.00	-1.4	0.08	0.07	+0.7	0.04	0.04
2B-F	0.00	+2.4	0.05	0.03	-5.0	0.07	0.04	+1.6	0.05	0.03
3B-F	0.00	+3.3	0.04	0.03	-9.5	0.07	0.05	+1.1	0.17	0.15
4B-F	n.d.	+1.2	0.03	0.02	-3.4	0.14	0.11	+0.6	0.06	0.05
5B-F	0.01	+0.6	0.04	0.02	-2.7	0.06	0.03	-0.6	0.04	0.03
6B-F	0.02	+1.0	0.04	0.03	-4.7	0.04	0.03	-0.4	0.05	0.04
7B-F	0.02	+3.2	0.04	0.03	-8.3	0.08	0.05	+2.3	0.14	0.10
8B-F	0.01	+1.1	0.04	0.03	-2.9	0.14	0.11	+0.8	0.06	0.04

Table 6. Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site C of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction ($km\ hr^{-1}$)	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Phase of Occurrence
1C-C	Algolake	5/27	1650	UB	730'00"	75'00"	17.5'	11.2	13.7 NNW	4	50	32.0	0.72	DD
2C-C	Lewis Wilson Foy	5/27	1714	UB	1000'00"	105'00"	19.9'	9.2	13.7 NNW	4	50	22.7	0.45	DD
3C-C	J. N. McWatters	8/16	1200	DB	730'00"	75'00"	n.d.	8.8	4.2 NE	1	60	1.0	0.01	DD
4C-C	Melody / Limassol (Scindia Nav. Co., Bombay)	8/16	1639	UB	520'00"	68'00"	Empty	14.5	11.7 NW	4	60	2.9	0.14	DD
5C-C	Nanticoke	8/16	1836	DB	730'00"	75'10"	26.0'	10.1	7.4 NW	4	60	1.2	0.07	DD, SG
6C-C	Montrealais	8/20	1040	DB	730'00"	75'00"	26.0'	9.2	5.6 NW	1	63	2.0	0.06	DD
7C-C	Canadoc	8/20	1045	UB	604'9"	62'00"	16.0'	11.6	4.7 NW	1	63	7.8	0.27	DD
8C-C	Paul H. Carnahan	8/20	1317	UB	730'00"	75'00"	17.0'	10.4	10.2 NW	3	63	12.2	0.35	DD
9C-C	Mesabi Miner	8/20	1330	DB	1004'00"	105'00"	26.0'	8.7	10.2 NW	3	61	2.4	0.10	
10C-C	Senneville	8/20	1432	UB	730'00"	75'00"	16.0'	9.9	9.3 NW	4	63	13.0	0.31	DD
11C-C	Nanticoke	8/20	1501	UB	730'00"	75'10"	26.0'	9.5	7.8 NW	2	63	13.2	0.50	DD
12C-C	Roger M. Kyes	8/20	1550	UB	680'00"	78'00"	27.0'	10.6	3.7 NW	1	63	13.5	0.48	DD
13C-C	Royalton	8/20	1724	UB	730'00"	75'00"	Empty	11.8	14.7 W	10	63	14.2	0.58	DD
14C-C	Canadian Navigator	8/20	1740	DB	729'10"	75'9.5"	26.0'	9.8	14.4 W	10	63	2.3	0.09	

Table 6 (Continued).

Passage I.D.	Initial	Standing Wave			Drawdown			Surge		
	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1C-C	n.d.	+6.0	0.18	0.17	-18.0	0.78	0.72	+18.0	0.31	0.29
2C-C	0.00	+6.3	0.16	0.13	-15.4	0.50	0.45	+7.3	0.38	0.32
3C-C	0.00	+0.2	0.00	0.00	-0.8	0.02	0.01	0.0	0.00	0.00
4C-C	0.01	+0.2	0.05	0.04	-2.9	0.16	0.14	+1.0	0.08	0.06
5C-C	n.d.	0.0	0.04	0.03	+1.2	0.09	0.07	0.0	0.08	0.07
6C-C	0.01	+0.4	0.02	0.01	-0.8	0.07	0.06	+1.2	0.04	0.02
7C-C	0.01	+0.8	0.12	0.11	-6.8	0.30	0.27	+1.0	0.08	0.06
8C-C	0.01	+3.8	0.06	0.05	-8.4	0.42	0.35	+2.5	0.16	0.14
9C-C	NT									
10C-C	0.01	+2.8	0.14	0.12	-8.2	0.36	0.31	+1.0	0.10	0.08
11C-C	0.01	+2.4	0.22	0.19	-9.6	0.56	0.50	+3.6	0.23	0.18
12C-C	0.00	+0.7	0.02	0.02	-10.4	0.51	0.48	+3.1	0.18	0.14
13C-C	0.01	+1.8	0.16	0.13	-12.4	0.69	0.58	+1.7	0.14	0.11
14C-C	NT									

Table 7. Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site C of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction ($km\ hr^{-1}$)	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Phase of Occurrence
1C-F	Ernest R. Breech	8/22	1157	DB	642'3"	67'00"	26.0'	9.9	3.0 W	0	60	1.2	0.03	DD
2C-F	American Mariner	8/22	1406	DB	728'00"	78'00"	26.0'	10.1	15.0 NW	5	60	2.1	0.07	DD, SG
3C-F	Algosoo	8/22	1502	UB	730'00"	75'00"	21.0'	9.7	15.5 NW	7	60	9.8	0.16	DD
4C-F	Canadoc	8/22	1508	DB	604'9"	62'00"	24.6'	9.9	15.8 NW	7	60	3.4	0.06	DD, SG
5C-F	J. L. Mauthe	8/22	1525	UB	647'00"	70'00"	15.5'	8.9	14.5 NW	7	60	8.6	0.14	DD
6C-F	Wolverine	8/23	1219	DB	630'00"	68'00"	26.0'	10.2	9.3 WNW	2	53	1.8	0.05	SG
7C-F	Canadian Explorer	8/23	1325	UB	730'00"	75'00"	15.7'	9.1	8.6 WNW	1	53	10.1	0.09	SG
8C-F	Edwin H. Gott	8/23	1350	DB	1004'00"	105'00"	28.0'	9.4	7.5 WNW	2	53	7.0	0.10	SG
9C-F	Joseph L. Block	8/23	1440	UB	728'00"	78'00"	17.1'	10.0	17.5 WNW	5	53	9.1	0.14	DD
10C-F	Herbert C. Jackson	8/24	1014	UB	690'2"	75'00"	25.0'	7.6	4.7 NW	0	56	7.8	0.11	SG
11C-F	Burns Harbor	8/24	1300	UB	1000'00"	105'00"	19.0'	10.8	1.5 NW	0	56	19.5	0.20	DD
12C-F	Mantadoc	8/27	1259	UB	607'9"	62'00"	13.0'	10.6	7.2 SE	4	66	7.1	0.14	DD
13C-F	Columbia Star	8/28	1305	UB	1000'00"	105'00"	21.0'	10.4	3.5 NE	1	62	22.8	0.17	DD
14C-F	Benson Ford	8/28	1605	UB	644'00"	67'00"	15.5'	10.2	9.0 NE	5	62	9.1	0.14	SG
15C-F	Edward B. Greene	8/28	1645	UB	767'00"	70'00"	21.5'	10.6	7.4 NE	3	62	17.8	0.21	DD

Table 7 (Continued).

	Initial	Standing Wave			Drawdown			Surge		
Passage I.D.	Mean Velocity ($m\ sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity ($m\ sec^{-1}$)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity ($m\ sec^{-1}$)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity ($m\ sec^{-1}$)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)
1C-F	0.00	0.0	0.00	0.00	-1.2	0.05	0.03	0.0	0.00	0.00
2C-F	0.04	0.0	0.08	0.05	-2.1	0.11	0.07	0.0	0.12	0.07
3C-F	0.03	+1.0	0.05	0.04	-8.8	0.18	0.16	+5.2	0.15	0.14
4C-F	0.04	+2.4	0.10	0.04	-1.0	0.09	0.06	+1.3	0.10	0.06
5C-F	0.04	+2.4	0.14	0.09	-6.2	0.18	0.14	0.0	0.14	0.09
6C-F	0.00	+0.2	0.03	0.02	-1.4	0.04	0.02	+0.4	0.07	0.05
7C-F	0.00	+0.8	0.03	0.01	-3.8	0.08	0.07	+6.3	0.12	0.09
8C-F	0.02	+2.0	0.07	0.04	-5.0	0.09	0.05	+0.1	0.15	0.10
9C-F	0.04	+1.5	0.12	0.09	-5.7	0.20	0.14	+3.4	0.17	0.13
10C-F	0.02	+1.9	0.03	0.02	-4.6	0.10	0.09	+3.2	0.12	0.11
11C-F	0.03	+2.8	0.06	0.04	-16.7	0.22	0.20	+7.2	0.19	0.13
12C-F	0.01	+1.7	0.08	0.06	-4.9	0.17	0.14	+2.2	0.12	0.07
13C-F	0.04	+2.6	0.07	0.06	-15.6	0.18	0.17	+7.2	0.19	0.16
14C-F	0.03	+3.1	0.10	0.08	-6.0	0.13	0.11	+2.8	0.18	0.14
15C-F	0.01	+4.4	0.10	0.08	-12.0	0.27	0.21	+5.8	0.18	0.14

Table 8. Physical data observed during commercial ship-passages and associated disturbances at the wetland face of Site D of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction (km hr^{-1})	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity (m sec^{-1})	Phase of Occurrence
1D-F	Walter A. Sterling	8/10	1100	UB	826'00"	75'00"	n.d.	10.5	5.0 NW	2	147	7.2	0.07	DD
2D-F	William Clay Ford	8/10	1130	UB	767'00	70'00"	17.0'	11.8	5.1 NW	2	147	6.9	0.05	DD
3D-F	Stewart J. Cort	8/10	1207	DB	1000'00"	105'00"	26.0'	9.2	6.1 NW	2	147	2.1	0.02	SG
4D-F	Herbert C. Jackson	8/10	1432	UB	690'2"	75'00"	25.0'	10.8	6.1 NW	2	147	3.8	0.04	DD
5D-F	Str. Comeaudoc	8/11	1534	UB	730'00"	75'6"	14.0'	9.8	4.3 N	n.d.	144	11.2	0.17	DD
6D-F	Montcliffe Hall	8/11	1734	UB	730'00"	75'9"	17.0'	12.3	Calm	0	144	5.8	0.10	DD
7D-F	Edgar B. Speer	8/13	1445	DB	1004'00"	105'00"	26.0'	9.0	3.9 n.d.	1	143	2.2	0.02	SG
8D-F	Chemical Transport	8/14	1025	DB	391'00"	55'4"	17.0'	11.1	Calm	0	144	0.1	0.00	—
9D-F	Burns Harbor	8/14	1325	DB	1000'00"	105'00"	26.0'	8.6	Calm	0	144	1.6	0.00	—
10D-F	Algolake	8/14	1348	UB	730'00"	75'00"	18.0'	10.2	Calm	0	144	4.6	0.08	DD
11D-F	American Mariner	8/14	1440	UB	728'00"	78'00"	26.0'	8.3	Calm	0	144	3.9	0.01	DD
12D-F	William J. DeLancey	8/14	1530	UB	1013'6"	105'00"	26.0'	8.8	22.9 NW	n.d.	144	5.0	0.07	DD
13D-F	Paul Thayer	8/14	1740	UB	630'00"	68'00"	18.0'	11.2	Calm	0	143	3.3	0.05	DD
14D-F	H. Lee White	8/14	1800	UB	704'00"	78'00"	26.0'	14.2	Calm	0	143	3.9	0.03	DD
15D-F	Beechglen	8/14	1815	UB	680'00"	60'00"	18.0'	10.8	Calm	0	143	3.4	0.04	DD
16D-F	Gaspe Transport	8/11	1340	DB	432'00"	60'00"	23.0'	10.3	6.5 E	n.d.	144	0.0	0.00	

Table 8 (Continued).

	Initial	Standing Wave			Drawdown			Surge		
Passage I.D.	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1D-F	0.00	+2.4	0.01	0.00	-4.8	0.08	0.07	+1.4	0.08	0.06
2D-F	0.00	+2.2	0.01	0.00	-4.7	0.06	0.05	+1.0	0.06	0.04
3D-F	0.00	+0.4	0.00	0.00	-1.7	0.00	0.00	0.0	0.02	0.02
4D-F	0.00	+0.9	0.02	0.01	-2.7	0.05	0.04	+0.8	0.02	0.02
5D-F	0.00	+4.2	0.02	0.02	-7.0	0.22	0.17	+2.8	0.06	0.05
6D-F	0.00	+2.2	0.00	0.00	-3.6	0.12	0.10	+1.9	0.02	0.01
7D-F	0.00	+0.9	0.01	0.01	-1.3	0.02	0.01	+0.5	0.04	0.02
8D-F	NSE									
9D-F	0.00	+0.6	0.00	0.00	-1.0	0.00	0.00	+0.2	0.00	0.00
10D-F	0.00	+1.6	0.00	0.00	-3.0	0.10	0.08	+1.4	0.00	0.00
11D-F	0.00	+1.8	0.00	0.00	-2.1	0.02	0.01	0.0	0.00	0.00
12D-F	0.00	+1.8	0.00	0.00	-3.2	0.08	0.07	+0.8	0.02	0.01
13D-F	0.00	+1.0	0.00	0.00	-2.3	0.06	0.05	+0.6	0.00	0.00
14D-F	0.00	+1.3	0.00	0.00	-2.6	0.04	0.03	0.0	0.00	0.00
15D-F	0.00	+1.2	0.00	0.00	-2.2	0.06	0.04	+0.8	0.00	0.00
16D-F	NSE									

Table 9. Physical data observed during commercial ship-passages and associated disturbances in a channelized area at the wetland face of Site E of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction ($km\ hr^{-1}$)	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity ($m\ sec^{-1}$)	Phase of Occurrence
1E-C	Canadian Navigator	8/3	1315	DB	729'10"	75'9.5"	26.0'	9.8	Calm	1	130	18.0	0.46	DD
2E-C	Charles E. Wilson	9/11	1205	DB	680'00"	78'00"	27.0'	8.5	4.8 NNE	1	128	15.5	0.54	DD
3E-C	Columbia Star	9/11	1340	DB	1000'00"	105'00"	27.5'	8.0	7.5 NNE	1	128	31.0	0.93	DD
4E-C	Edward B. Greene	9/11	1520	DB	767'00"	70'00"	27.0'	9.5	3.1 NNE	1	128	32.5	1.00	DD
5E-C	Murray Bay	9/12	1152	DB	730'00"	75'3"	27.0'	9.6	7.8 SE	6	132	42.8	0.71	DD
6E-C	Achilles	9/12	1440	UB	579'11"	75'00"	14.5'	12.3	13.6 SE	n.d.	132	4.4	0.08	SG
7E-C	Chemical Transport	9/13	1055	UB	391'00"	55'4"	n.d.	9.3	8.5 NE	1	123	0.9	0.03	
8E-C	Cason J. Callaway	9/13	1120	DB	767'00"	70'00"	27.0'	8.4	11.1 NE	1	123	10.9	0.23	DD
9E-C	Whitefish Bay	9/13	1140	DB	730'00"	75'00"	26.5'	8.5	10.0 NE	1	123	12.0	0.20	DD
10E-C	Canadoc	9/13	1211	DB	604'9"	62'00"	n.d.	9.7	7.3 NE	1	123	15.8	0.31	DD
11E-C	Canadian Ranger	9/13	1315	UB	730'00"	75'00"	27.0'	10.3	14.4 ENE	n.d.	123	2.2	0.02	SW, DD
12E-C	T. R. McLagan	9/13	1403	UB	714'6"	70'3"	16.0'	10.1	13.6 ENE	10	123	2.8	0.02	SW, DD, SG
13E-C	Canadian Hunter	9/13	1424	UB	730'00"	75'00"	17.0'	11.2	18.0 ENE	10	123	3.3	0.05	SG
14E-C	Michalis	9/13	1506	UB	525'00"	75'00"	13.0'	9.1	18.0 ENE	10	123	0.0	0.03	
15E-C	Nanticoke	9/14	1349	UB	730'00"	75'10"	16.0'	11.1	8.4 NNE	8	124	1.4	0.08	SG
16E-C	Chemical Transport	9/14	1414	DB	391'00"	55'4"	13.0'	10.3	10.0 NNE	8	124	10.9	0.25	DD
17E-C	American Republic	9/14	1500	DB	634'10"	68'00"	25.0'	9.0	8.1 NNE	7	124	11.3	0.27	DD
18E-C	James R. Barker	9/18	0940	DB	1004'00"	105'00"	26.0'	7.3	10.1 SSW	6	126	15.2	0.28	DD
19E-C	Arthur M. Anderson	9/18	1138	DB	767'00"	70'00"	26.0'	8.7	13.1 SW	6	126	12.5	0.27	DD

Table 9 (Continued).

I.D.	Initial	Standing Wave			Drawdown			Surge		
	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1E-C	0.03	+2.3	0.11	0.09	-15.7	0.54	0.46	+0.8	0.42	0.36
2E-C	0.00	+2.4	0.05	0.04	-13.1	0.59	0.54	+0.8	0.20	0.17
3E-C	n.d.	+4.6	0.11	0.09	-26.4	1.11	0.93	+1.6	0.35	0.25
4E-C	0.00	+5.3	0.12	0.09	-27.2	1.32	1.00	+1.2	0.16	0.11
5E-C	0.01	+7.8	0.17	0.15	-35.0	0.79	0.71	+3.4	0.03	0.01
6E-C	0.02	+2.3	0.08	0.06	-2.1	0.09	0.06	0.0	0.12	0.08
7E-C	NSE									
8E-C	0.02	+1.8	0.08	0.06	-9.1	0.28	0.23	+0.3	0.17	0.14
9E-C	0.00	+1.6	0.07	0.06	-10.4	0.23	0.20	0.0	0.21	0.13
10E-C	0.03	+3.3	0.13	0.09	-12.5	0.36	0.31	+2.0	0.19	0.13
11E-C	0.01	+0.8	0.04	0.02	-1.4	0.04	0.02	0.0	0.02	0.01
12E-C	0.01	+1.2	0.03	0.02	-1.6	0.03	0.02	0.0	0.04	0.02
13E-C	0.02	+0.5	0.04	0.03	-2.8	0.06	0.04	0.0	0.09	0.05
14E-C	NSE									
15E-C	0.02	0.0	0.03	0.02	-1.4	0.07	0.06	0.0	0.10	0.08
16E-C	0.02	+1.8	0.02	0.01	-9.1	0.29	0.25	+0.5	0.08	0.07
17E-C	0.00	+1.8	0.07	0.05	-9.5	0.31	0.27	+0.5	0.13	0.09
18E-C	0.02	+1.0	0.11	0.09	-14.2	0.30	0.28	+1.2	0.19	0.14
19E-C	0.02	+1.9	0.08	0.05	-10.6	0.34	0.27	+0.6	0.10	0.09

Table 10. Physical data observed during commercial ship-passages and associated disturbances in the near-shore waters at Site F of the St. Marys River during the open-water period of 1984.

Passage I.D.	Vessel Name	Date	Time (EDT)	Direction	Length	Beam	Amid-Ships Draft	Vessel Speed (mph)	Wind Speed and Direction (km hr^{-1})	Wave Height (cm)	Water Depth (cm)	Total Change in Water Level (cm)	Maximum 10 Sec Mean Velocity (m sec^{-1})	Phase of Occurrence
1F	J. A. W. Iglehart	9/5	1110	UB	501'6"	68'3"	26.0'	6.8	11.5 NNW	2	111	14.4	0.21	SG
2F	Royalton	9/5	1243	DB	730'00"	75'00"	24.0'	10.1	18.0 NNW	7	111	35.6	0.66	SG
3F	Algosoo	9/5	1400	UB	730'00"	75'00"	19.0'	7.3	19.6 NNW	7	111	16.2	0.24	SG
4F	Steelcliffe Hall	9/5	1600	DB	730'00"	75'9"	26.0'	10.8	17.5 NNW	7	111	44.4	0.77	SG
5F	Silver Isle	9/6	1114	UB	730'00"	75'00"	13.0'	10.7	5.1 SSE	0	117	7.3	0.14	SG
6F	Canadian Enterprise	9/6	1146	UB	730'00"	75'10"	16.0'	9.2	6.0 SSE	1	117	8.4	0.17	DD
7F	Senneville	9/6	1235	DB	730'00"	75'00"	27.0'	9.7	6.0 SSE	1	117	23.4	0.55	SG
8F	Belle River	9/6	1425	DB	1000'00"	105'00"	26.0'	9.4	6.0 SSE	2	117	70.0	1.01	SG
9F	Edward L. Ryerson	9/6	1505	UB	730'00"	75'00"	16.0'	7.3	8.6 WSW	7	117	12.7	0.20	SG
10F	William J. DeLancey	9/6	1615	UB	1013'6"	105'00"	22.0'	6.4	12.8 WSW	7	117	22.1	0.35	SG
11F	John B. Aird	9/6	1650	DB	730'00"	75'10"	28.0'	8.5	10.8 WSW	3	117	9.0	0.23	SG
12F	Beechglen	9/6	1655	DB	680'00"	60'00"	24.0'	10.3	10.8 WSW	3	117	26.0	0.56	SG
13F	Jensen Star	9/6	1747	UB	404'00"	60'00"	15.0'	7.5	7.2 WSW	3	117	6.2	0.07	SG
14F	Cedarglen	9/6	1922	UB	603'9"	60'00"	12.5'	4.8	9.2 S	3	117	1.5	0.13	
15F	Jensen Star	9/10	1335	DB	404'00"	60'00"	16.0'	9.0	13.3 W	2	117	3.3	0.11	SG
16F	Kemel II (Istanbul)	9/10	1340	UB	Unknown	Unknown	10.1'	–	13.3 W	2	117	2.8	0.11	SW
17F	Beechglen	9/10	1600	UB	680'00"	60'00"	15.0'	7.0	15.3 NW	3	117	7.7	0.15	SG
18F	Stewart J. Cort	9/10	1715	DB	1000'00"	105'00"	27.0'	8.5	15.0 NW	3	117	34.3	0.34	SG
19F	Whitefish Bay	9/10	1740	UB	730'00"	75'00"	12.0'	7.8	10.9 NW	3	117	5.5	0.13	DD, SG
20F	Cedarglen	9/10	1753	DB	603'9"	60'00"	26.0'	9.2	10.9 NW	3	117	9.4	0.24	SG
21F	V. W. Scully	9/10	1815	DB	730'00"	75'00"	26.0'	10.1	14.0 NW	5	117	28.9	0.78	SG
22F	Canadoc	9/10	1835	UB	604'9"	62'00"	13.0'	8.9	9.9 NW	5	117	7.2	0.19	SG

Table 10 (Continued).

Passage I.D.	Initial	Standing Wave			Drawdown			Surge		
	Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})	Water Level Δ From Baseline (cm)	Maximum Instant. Velocity (m sec^{-1})	Maximum 10 Sec Mean Velocity (m sec^{-1})
1F	0.03	+2.6	0.08	0.05	-7.2	0.18	0.12	+7.2	0.25	0.21
2F	n.d.	+2.1	0.11	0.09	-20.8	0.22	0.20	+14.8	0.72	0.66
3F	0.06	+2.2	0.12	0.09	-9.7	0.16	0.14	+6.5	0.30	0.24
4F	0.06	+2.0	0.14	0.12	-26.2	0.69	0.65	+18.2	0.91	0.77
5F	0.06	+0.4	0.10	0.08	-6.0	0.15	0.13	+1.3	0.16	0.14
6F	0.06	+2.9	0.15	0.13	-5.5	0.20	0.17	+1.2	0.19	0.15
7F	0.06	+1.4	n.d.	n.d.	-14.4	0.42	0.40	+9.0	0.61	0.55
8F	0.06	+2.5	0.16	0.14	-32.0	0.92	0.78	+38.0	1.15	1.01
9F	0.02	+2.4	0.06	0.05	-7.9	0.10	0.08	+4.8	0.23	0.20
10F	0.04	+3.7	0.05	0.03	-18.2	0.28	0.24	+3.9	0.38	0.35
11F	n.d.	+2.4	0.12	0.10	-6.6	0.17	0.15	+2.4	0.26	0.23
12F	n.d.	+2.4	0.17	0.14	-15.3	0.48	0.45	+10.7	0.62	0.56
13F	0.02	+0.8	0.06	0.04	-3.7	0.07	0.05	+2.5	0.10	0.07
14F	NSE									
15F	0.04	+0.8	0.06	0.04	-2.5	0.10	0.08	+0.8	0.12	0.11
16F	0.04	+0.4	0.15	0.11	-2.4	0.10	0.09	+0.4	0.10	0.09
17F	0.05	+0.6	0.07	0.06	-5,1	0.12	0.10	+2.6	0.19	0.15
18F	0.09	+2.6	0.15	0.13	-24.8	0.29	0.28	+9.5	0.38	0.34
19F	0.06	+1.7	0.12	0.10	-3.5	0.15	0.13	+2.0	0.15	0.13
20F	0.07	+2.3	0.02	0.01	-7.0	0.09	0.07	+2.4	0.25	0.24
21F	0.07	+3.1	0.12	0.09	-15.3	0.32	0.29	+13.6	0.83	0.78
22F	0.04	+2.1	0.10	0.08	-4.4	0.18	0.16	+2.8	0.20	0.19

Table 11. Organic carbon and residue values for various ship-passage events at Sites B, C, D, and E of the St. Marys River during the open-water period of 1984.

Passage ID: Passage Date:	5B-C 7/29	9B-C 7/30	13B-C 8/1	16B-C 8/1	2B-F 8/30	3B-F 8/30	7B-F 8/30
Total Organic Carbon (mg l^{-1})							
Initial	3.2	3.2	3.3	3.8	4.3	4.4	4.7
Standing Wave	3.7	3.5	3.7	3.4	4.1	4.4	4.8
Drawdown	3.3	3.8	3.5	3.6	4.8	4.5	4.4
Surge	3.4	3.5	3.7	3.7	4.5	4.5	4.4
Post-passage	-	3.7	3.5	3.9	4.4	4.5	4.3
Particulate Organic Carbon (mg l^{-1})							
Initial	0.1	0.1	-0.8	0.5	0.2	0.2	0.1
Standing Wave	0.6	0.3	-0.9	-0.6	0.0	0.1	0.3
Drawdown	0.3	0.7	-0.5	0.3	0.8	0.3	0.1
Surge	0.4	0.3	-0.3	0.2	0.4	0.2	-0.6
Post-passage	-	0.5	-0.9	0.5	0.3	0.3	-0.7
Dissolved Organic Carbon (mg l^{-1})							
Initial	3.1	3.1	4.1	3.3	4.1	4.2	4.6
Standing Wave	3.1	3.2	4.6	4.0	4.1	4.3	4.5
Drawdown	3.0	3.1	4.0	3.3	4.0	4.2	4.3
Surge	3.0	3.2	4.0	3.5	4.1	4.3	5.0
Post-passage	-	3.2	4.4	3.4	4.1	4.2	5.0
Total Residue (mg l^{-1})							
Initial	115.8	117.0	117.6	115.8	124.4	115.2	131.0
Standing Wave	137.2	121.4	121.0	113.8	124.2	127.4	127.6
Drawdown	112.0	123.2	126.6	118.6	122.4	126.6	127.6
Surge	118.0	132.4	117.4	115.8	130.2	126.0	125.4
Post-passage	123.6	114.0	132.2	113.0	125.0	124.4	121.4
Particulate Residue (mg l^{-1})							
Initial	2.4	20.2	15.0	13.2	20.0	11.6	39.0
Standing Wave	25.4	16.0	15.4	13.2	20.2	28.2	35.6
Drawdown	8.0	13.4	20.2	16.2	18.2	26.0	33.0
Surge	11.8	26.2	16.0	10.2	29.4	25.2	23.8
Post-passage	9.6	5.0	33.4	8.0	23.8	26.8	19.6
Dissolved Residue (mg l^{-1})							
Initial	113.4	96.8	102.6	102.6	104.4	103.6	92.0
Standing Wave	111.8	105.4	105.6	100.6	104.0	99.2	92.0
Drawdown	104.0	109.8	106.4	102.4	104.2	100.6	94.6
Surge	106.2	106.2	101.4	105.6	100.8	100.8	101.6
Post-passage	114.0	109.0	98.8	105.0	101.2	97.6	101.8

Table 11 (Continued).

Passage ID:	4C-C	7C-C	8C-C	12C-C	3C-F	10C-F	11C-F
Passage Date:	8/30	8/22	8/22	8/22	8/22	8/24	8/24
Total Organic Carbon (mg l^{-1})							
Initial	4.1	5.1	5.6	4.8	4.7	4.7	4.2
Standing Wave	4.2	5.5	6.0	5.2	5.1	4.6	4.1
Drawdown	3.9	5.5	4.9	5.8	4.3	4.6	4.0
Surge	4.3	5.7	5.5	4.9	4.3	3.9	4.0
Post-passage	4.0	6.0	5.7	4.8	4.3	4.4	4.0
Particulate Organic Carbon (mg l^{-1})							
Initial	0.8	0.6	0.3	0.3	1.1	1.4	0.8
Standing Wave	0.1	0.5	0.9	0.8	1.5	1.2	0.9
Drawdown	0.5	0.8	0.1	1.3	0.3	1.1	0.7
Surge	0.4	1.2	1.0	0.5	0.3	0.4	0.8
Post-passage	0.2	1.5	0.1	0.2	0.3	1.1	0.8
Dissolved Organic Carbon (mg l^{-1})							
Initial	3.3	4.5	5.3	4.5	3.6	3.3	3.4
Standing Wave	4.1	5.0	5.1	4.4	3.6	3.4	3.2
Drawdown	3.4	4.7	4.8	4.5	4.0	3.5	3.3
Surge	3.9	4.5	4.5	4.4	4.0	3.5	3.2
Post-passage	3.8	4.5	5.6	4.6	4.0	3.3	3.2
Total Residue (mg l^{-1})							
Initial	118.0	114.6	115.6	113.2	105.6	142.6	127.2
Standing Wave	108.6	110.2	126.8	125.8	110.4	126.8	121.0
Drawdown	108.0	116.6	127.4	117.8	110.2	128.4	122.2
Surge	108.4	113.0	120.0	128.2	116.6	134.0	132.2
Post-passage	106.6	122.4	126.4	127.0	120.8	132.0	122.8
Particulate Residue (mg l^{-1})							
Initial	16.6	10.2	14.8	11.4	1.6	37.6	25.6
Standing Wave	6.2	6.6	22.4	29.4	6.2	23.4	21.0
Drawdown	7.8	15.4	23.2	23.0	9.4	18.4	22.2
Surge	3.0	11.0	10.8	28.2	14.6	23.0	21.0
Post-passage	0.4	20.4	13.4	29.6	16.6	24.8	20.2
Dissolved Residue (mg l^{-1})							
Initial	101.4	104.4	100.8	101.8	104.0	105.0	101.6
Standing Wave	102.4	103.6	104.4	96.4	104.2	103.4	100.0
Drawdown	100.2	101.2	104.2	94.8	100.8	110.0	100.0
Surge	105.4	102.0	109.2	100.0	102.0	111.0	111.2
Post-passage	106.2	102.0	113.0	97.4	104.2	107.2	102.6

Table 11 (Continued).

Passage ID: Passage Date:	13C-F 8/28	15C-F 8/28	5D-F 8/11	11D-F 8/14	1E-C 8/3
Total Organic Carbon (mg l^{-1})					
Initial	6.3	5.5	4.8	4.3	4.5
Standing Wave	6.7	5.5	4.1	5.2	3.6
Drawdown	6.3	5.4	4.9	4.3	4.0
Surge	6.5	5.5	5.1	3.8	4.0
Post-passage	6.1	5.8	3.9	4.7	3.3
Particulate Organic Carbon (mg l^{-1})					
Initial	0.4	-0.1	1.5	-0.2	-1.1
Standing Wave	0.5	-0.5	1.0	1.4	0.1
Drawdown	0.0	-0.1	2.0	-0.1	0.7
Surge	0.0	-0.2	2.0	-0.8	0.3
Post-passage	-0.7	0.5	0.6	0.5	-0.4
Dissolved Organic Carbon (mg l^{-1})					
Initial	5.9	5.6	3.3	4.5	5.6
Standing Wave	6.2	6.0	3.1	3.8	3.5
Drawdown	6.3	5.5	2.9	4.4	3.3
Surge	6.5	5.7	3.1	4.6	3.7
Post-passage	6.8	5.3	3.3	4.2	3.7
Total Residue (mg l^{-1})					
Initial	109.4	137.0	104.0	99.6	108.0
Standing Wave	122.2	127.0	107.2	104.2	123.0
Drawdown	134.8	121.8	105.2	106.2	120.7
Surge	129.4	114.2	105.6	107.4	142.6
Post-passage	129.8	119.8	101.6	101.8	115.4
Particulate Residue (mg l^{-1})					
Initial	2.8	22.2	4.2	2.8	7.6
Standing Wave	23.4	13.4	9.6	5.2	1.8
Drawdown	35.2	18.2	4.6	7.4	47.5
Surge	21.8	2.8	6.2	10.2	40.4
Post-passage	16.8	10.0	2.0	7.0	9.6
Dissolved Residue (mg l^{-1})					
Initial	106.6	114.8	99.8	96.8	100.4
Standing Wave	98.8	113.6	97.6	99.0	121.2
Drawdown	99.6	103.6	100.6	98.8	73.2
Surge	107.6	111.4	99.4	97.2	102.2
Post-passage	113.0	109.8	99.6	94.8	105.8

Table 12. Chlorophyll a and sediment accumulation values for various ship-passage events at Sites B, C, D, and E of the St. Marys River during the open-water period of 1984.

Passage ID:	5B-C	9B-C	13B-C	16B-C	2B-F	3B-F	7B-F
Passage Date:	7/29	7/30	8/1	8/1	8/30	8/30	8/30
Chlorophyll a (ug l^{-1})							
Initial	1.13	1.49	0.98	1.21	0.94	0.64	0.82
Standing Wave	1.19	1.47	0.82	1.27	1.13	0.73	0.84
Drawdown	1.23	1.51	1.27	1.29	1.14	0.77	0.82
Surge	1.11	1.39	1.39	1.58	1.12	0.79	1.26
Post-passage	1.29	1.47	1.31	1.23	1.14	0.81	0.82
Sediment Trap Accumulations (g)							
Ambient Accumulation							
Upriver	0.24	0.84	0.17	0.17	0.21	0.21	0.21
Downriver	0.54	1.97	0.27	0.27	0.19	0.19	0.19
Wetland	0.16	0.63	0.25	0.25	0.60	0.60	0.60
Channel	0.20	0.80	0.81	0.81	0.43	0.43	0.43
Passage Accumulation							
Upriver	0.68	1.72	0.44	0.30	0.27	0.24	0.20
Downriver	0.41	2.77	0.20	0.43	0.37	0.09	0.13
Wetland	0.37	1.22	0.35	0.45	0.46	0.20	0.30
Channel	0.42	5.32	0.35	0.27	0.34	0.09	0.21
Net Accumulation [(Passage)-(Ambient)]							
Upriver	0.44	0.88	0.27	0.13	0.06	0.03	-0.01
Downriver	-0.12	0.80	-0.07	0.16	0.18	-0.10	-0.05
Wetland	0.21	0.59	0.10	0.20	-0.14	-0.41	-0.30
Channel	0.21	4.51	-0.46	-0.53	-0.09	-0.34	-0.22

Table 12 (Continued).

Passage ID:	4C-C	7C-C	8C-C	12C-C	3C-F	10C-F	11C-F
Passage Date:	8/30	8/22	8/22	8/22	8/22	8/24	8/24
Chlorophyll *a* (ug l^{-1})							
Initial	0.35	0.51	0.59	0.90	0.78	0.72	0.62
Standing Wave	0.42	0.51	0.51	0.74	0.78	0.84	0.59
Drawdown	0.34	0.44	0.61	0.74	0.84	0.66	0.45
Surge	0.35	0.47	0.44	0.76	0.76	0.57	0.84
Post-passage	0.34	0.51	0.62	0.68	0.78	0.68	0.65
Sediment Trap Accumulations (g)							
Ambient Accumulation							
Upriver	0.12	0.08	0.04	0.08	0.11	0.14	0.08
Downriver	0.06	0.03	0.02	0.06	0.20	0.14	0.07
Wetland	0.12	0.05	0.02	0.05	0.10	0.15	0.09
Channel	0.08	0.06	0.03	0.04	0.48	0.21	0.08
Passage Accumulation							
Upriver	0.64	0.17	1.55	0.20	0.66	0.17	0.21
Downriver	0.20	0.08	0.43	1.62	1.07	0.16	0.13
Wetland	0.12	0.09	0.36	0.27	0.51	0.18	0.09
Channel	0.38	0.09	0.49	0.55	0.96	0.18	0.18
Net Accumulation [(Passage)-(Ambient)]							
Upriver	0.52	0.09	1.51	0.12	0.55	0.03	0.14
Downriver	0.13	0.05	0.41	1.57	0.87	0.02	0.06
Wetland	-0.01	0.04	0.34	0.22	0.41	0.03	.00
Channel	0.31	0.03	0.46	0.51	0.48	-0.04	0.10

Table 12 (Continued).

Passage ID:	13C-F	15C-F	5D-F	11D-F	1E-C
Passage Date:	8/28	8/28	8/11	8/14	8/3
Chlorophyll _a_ (ug l^{-1})					
Initial	0.76	0.70	0.63	0.43	1.37
Standing Wave	0.78	0.65	0.76	0.55	1.06
Drawdown	0.74	0.68	0.68	0.55	1.31
Surge	0.82	0.63	0.55	0.57	1.33
Post-passage	0.96	0.63	0.70	0.64	1.33
Sediment Trap Accumulations (g)					
Ambient Accumulation					
Upriver	0.06	0.18	0.05	0.10	0.02
Downriver	0.04	0.13	0.02	0.04	0.02
Wetland	0.09	0.07	0.05	0.07	0.06
Channel	0.05	0.14	0.03	0.01	0.03
Passage Accumulation					
Upriver	0.15	0.54	0.44	0.07	0.12
Downriver	0.31	0.40	0.18	0.05	0.14
Wetland	0.35	0.19	0.46	0.04	0.06
Channel	0.19	0.18	0.10	0.13	0.18
Net Accumulation [(Passage)-(Ambient)]					
Upriver	0.09	0.36	0.39	-0.03	0.10
Downriver	0.27	0.27	0.15	0.01	0.11
Wetland	0.25	0.11	0.41	-0.03	.00
Channel	0.14	0.04	0.07	0.12	0.15

DISCUSSION

Frequency histograms of vessel length and beam for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River are presented in Figures 9 and 10, respectively. The greatest number of ship-passages were for vessels that had an overall length between 700 and 799 ft (213 and 243 m); 49% (64 of the 130 events) were of this size category. The next largest largest size class was for ships less than 700 ft in length, constituting 32% of the events. Eighteen percent of the events were of the largest size category of vessels that travel the Great Lakes (≥ 1000 ft or 305 m). There were no events for vessels 900-999 ft (274-304 m) since there are none of this size class on Great Lakes waters (Greenwood and Dills 1984). Only one of the events was for a ship 800-899 ft (244-274 m) in length. Greenwood and Dills (1984) show this size class to be rare on the Great Lakes, making up only 2% of powered bulk freighters and self-unloaders. Table 13 shows the size frequencies for the 130 events that were monitored in this study.

Table 13. Frequencies of size class distribution for vessel length (in feet) for the 130 events monitored during the open-water period of 1984 on the St. Marys River.

Size Class	Frequency
≤700	32%
700-799	49%
800-899	1%
900-999	0%
≥1000	18%

Figure 10 shows that 76% of the events were of vessels that had beams between 60 and 79 ft (18 and 24 m). Eighteen percent of the events were of the the largest size class for beams. This is represented solely by 1000 footers, all of which have beams of 105 ft (32 m). Only one other ship listed in Greenwood and Dills (1984) has a beam of this magnitude; it is the Roger Blough which is 858 ft (262 m) long and 105 ft (32 m) wide. This vessel was not monitored during this study.

Table 14 presents data on vessel speed for the 130 events. The events have been separated by the direction of travel. The United States Coast Pilot 6 (NOAA 1984) indicates that the speed limit for all downbound vessels is 10 mph for the six sites studied; upbound speed limits are 12 mph for Sites A through E and 8 mph at Site F.

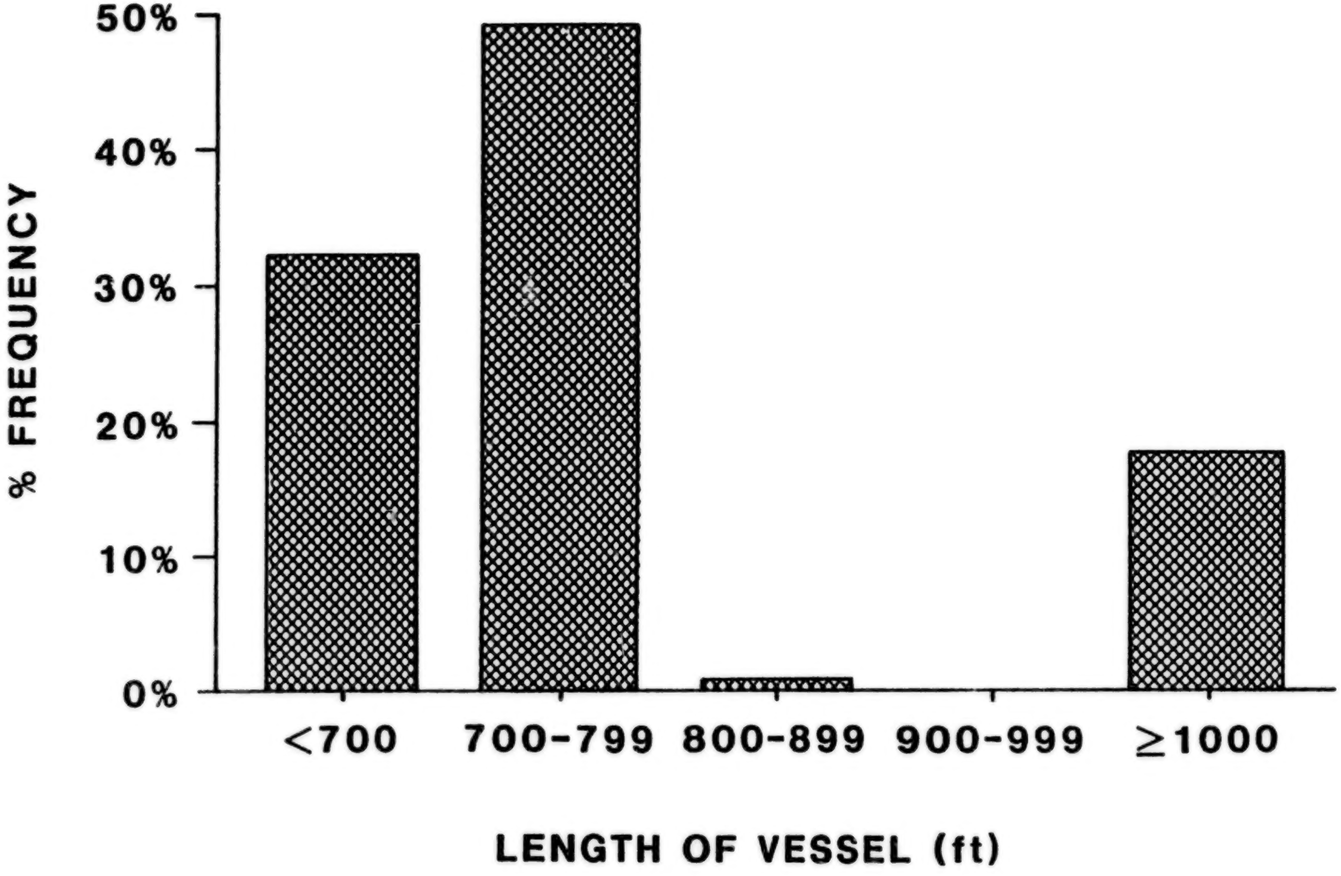

Figure 9. Frequency distribution of vessel lengths for the 130 commercial ship-passages monitored during the open-water period of 1984 on the St. Marys River.

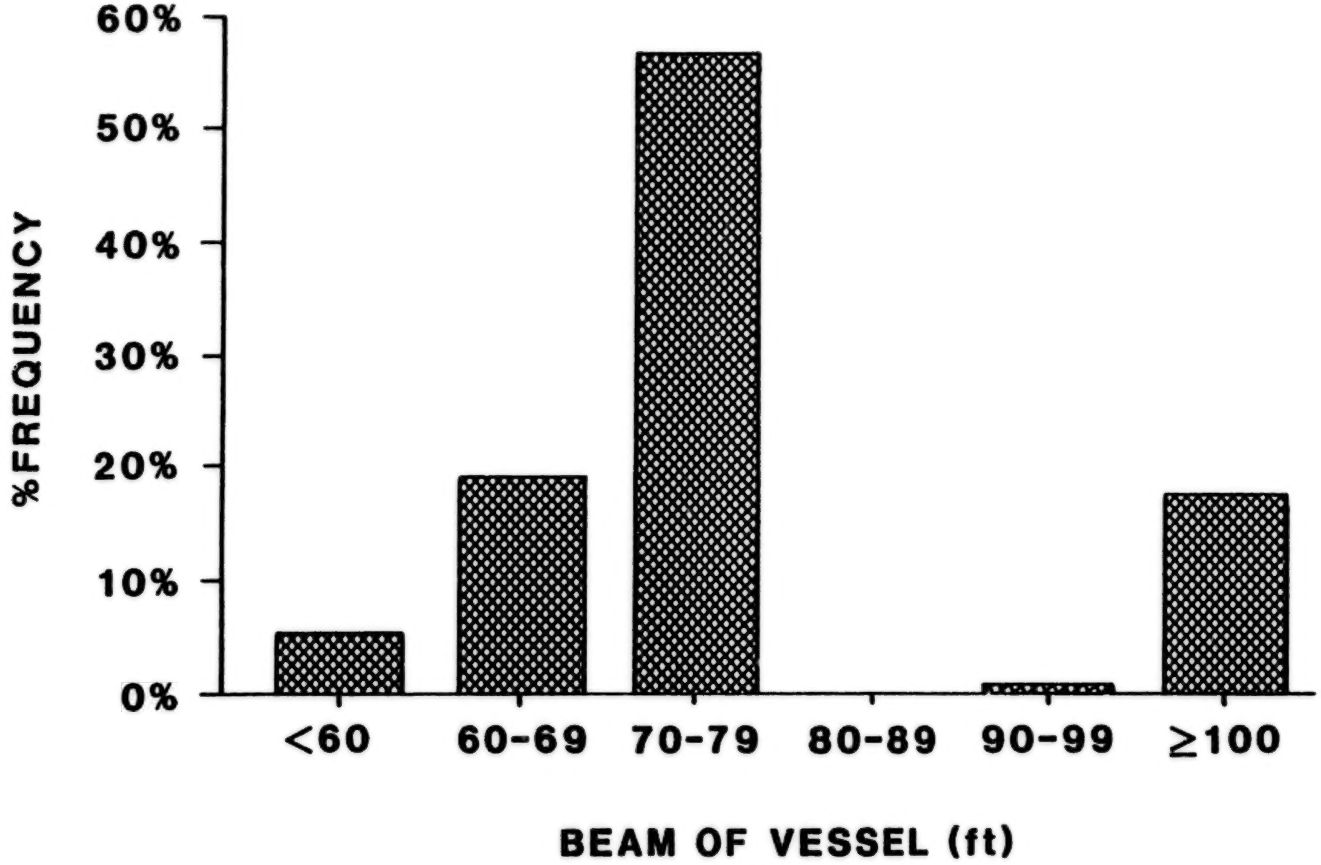

Figure 10. Frequency distribution of vessel beams for the 130 commercial ship-passages monitored during the open-water period of 1984 on the St. Marys River.

Table 14. Frequency distribution of vessel speed for the 130 ship-passage events monitored at various sites of the St. Marys River during the open-water period of 1984.

	Downbound		Upbound	
Speed (mph)	Frequency	% Frequency	Frequency	% Frequency
≤7.0	0	0.0	6	8.2
7.1-8.0	2	3.5	7	9.6
8.1-9.0	18	31.6	6	8.2
9.1-10.0	25	43.9	15	20.5
10.1-11.0	11	19.3	21	28.8
11.1-12.0	1	1.8	12	16.4
>12.0	0	0.0	6	8.2
Totals	57	100.0	73	100.0

Table 14 indicates that over 21% of the downbound vessels were traveling in excess of 10 mph. However, 10 of the 12 events reported as exceeding the speed limit (see Tables 3 through 8) did so by only 0.3 mph or less. This amount is within the range of error for this calculation; for example, a 2% error in calculated vessel speed results from a 1 second error in the timing of the ship passing a fixed point. Therefore, it appears that only two events were for ships that were actually exceeding the speed limit. One was when the Chemical Transport passed Site D-F on 14 August 1984 traveling at a calculated speed of 11.1 mph (Table 8) and the other was at Site F on 5 September 1984 when the Steelcliffe Hall passed the sampling station at a rate of speed of 10.8 mph (Table 10).

Nine upbound vessels were observed to be speeding. Three of those were at Site F where the speed limit was 8 mph; the calculated speeds were 8.9, 9.2, and 10.7 mph (Table 10). The other six occurred at Sites B, C, D, and E where the speed limit was 12 mph. Two of the six had recorded speeds of 12.3 mph while the other four were ≥12.5 mph. Two ships were traveling in excess of 14 mph: they were the Melody/Limassol (Passage I.D. 4C-C, Table 6) and the H. Lee White (Passage I.D. 14D-F, Table 8).

Wuebben (1983) has described the general pattern of water movement that is created along shorelines during vessel-passage. Figures 11 through 17 graphically depict this water cycle for seven of the eight sampling sites on the St. Marys River that were monitored during the open-water season of 1984. Each figure represents an event which typifies the water cycle for that site. No event for Site A was drawn since most ship-passage events did not produce a noticeable pattern (see Table 3). The location of the sites are shown in Figures 2 and 3. The dark line at the end of the arrow for each site location in Figure 2 represents the face of the wetland, its orientation to the navigation channel, and distance from both the shore and the center of the navigation channels.

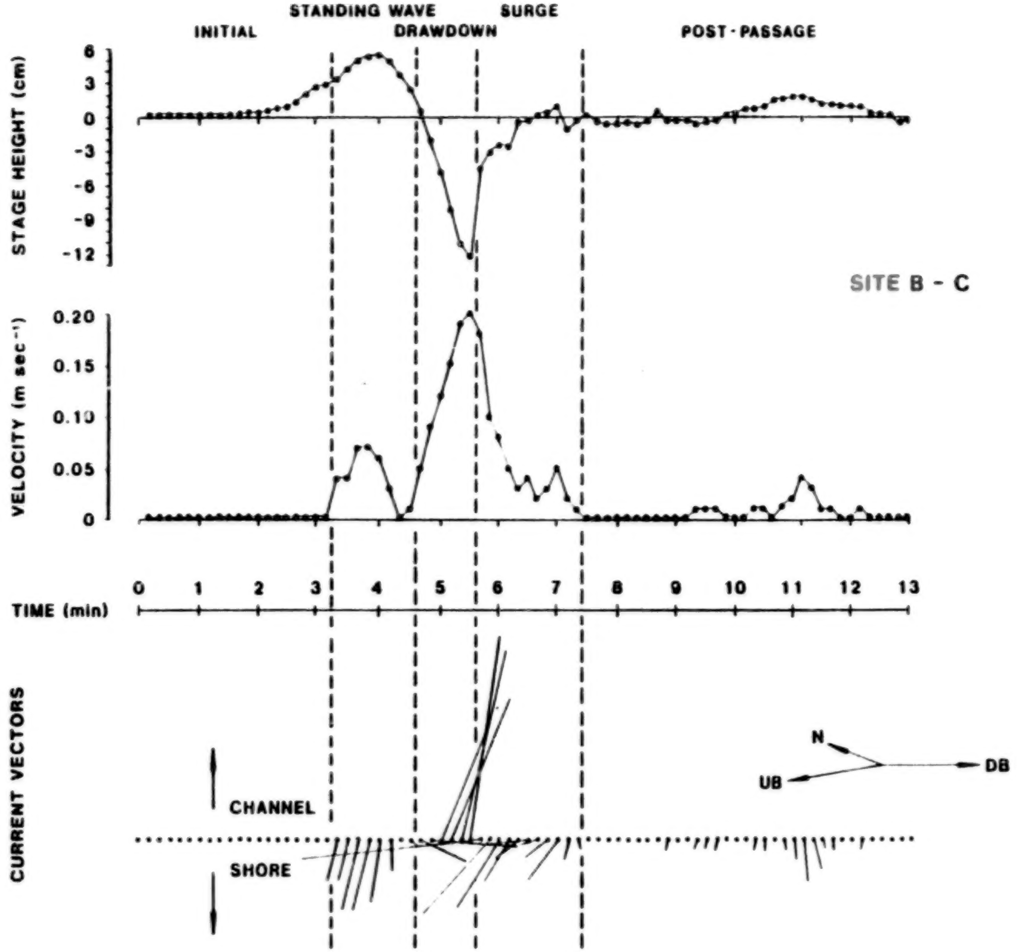

Figure 11. Water level changes and current vectors generated by the upbound passage of the Ashley Lykes (Passage 10B-C of Table 4). Dashed vertical lines separate the phases of the water cycle.

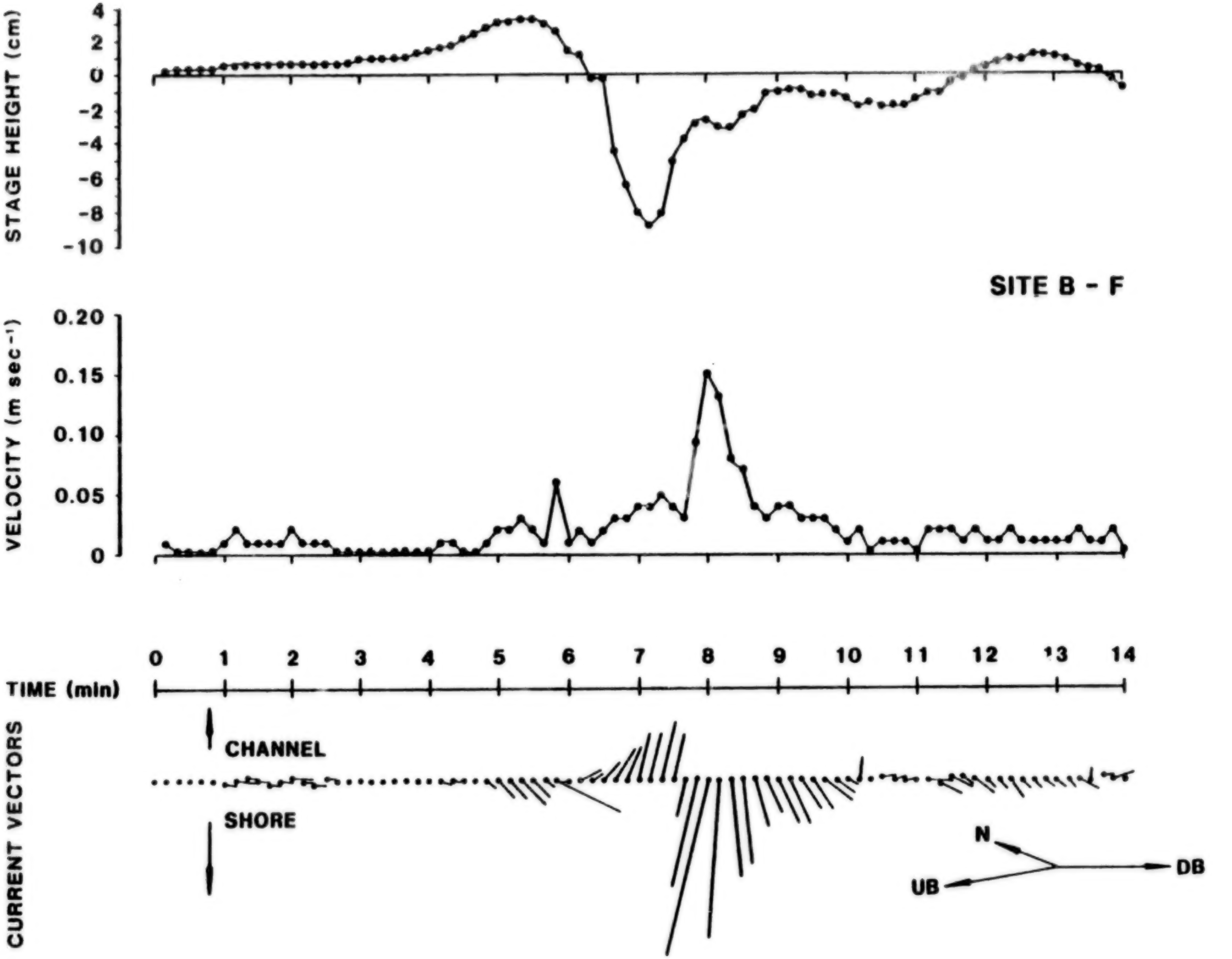

Figure 12. Water level changes and current vectors generated by the downbound passage of the Rimouski (Passage 3B-F of Table 5).

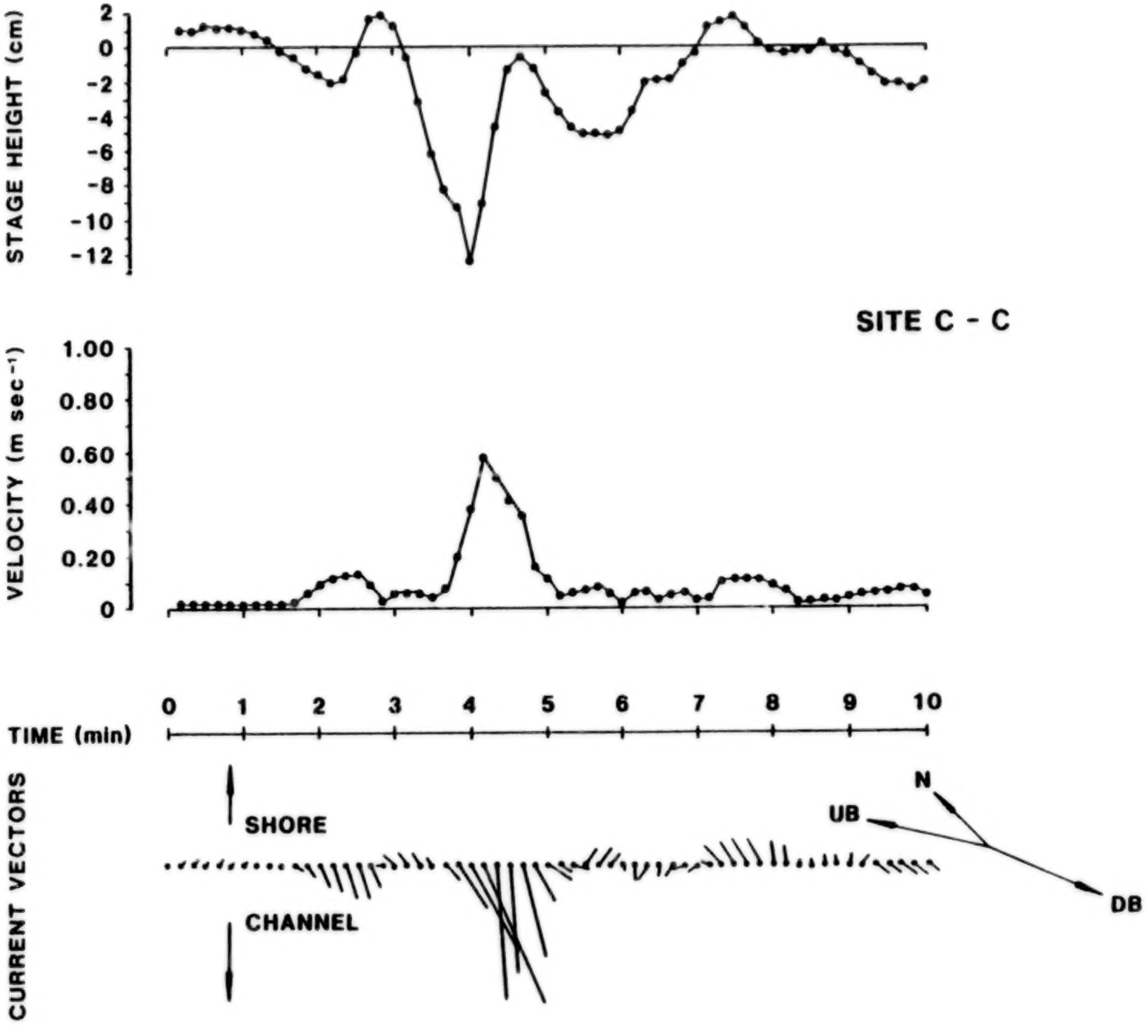

Figure 13. Water level changes and current vectors generated by the upbound passage of the Royalton (Passage 13C-C of Table 6).

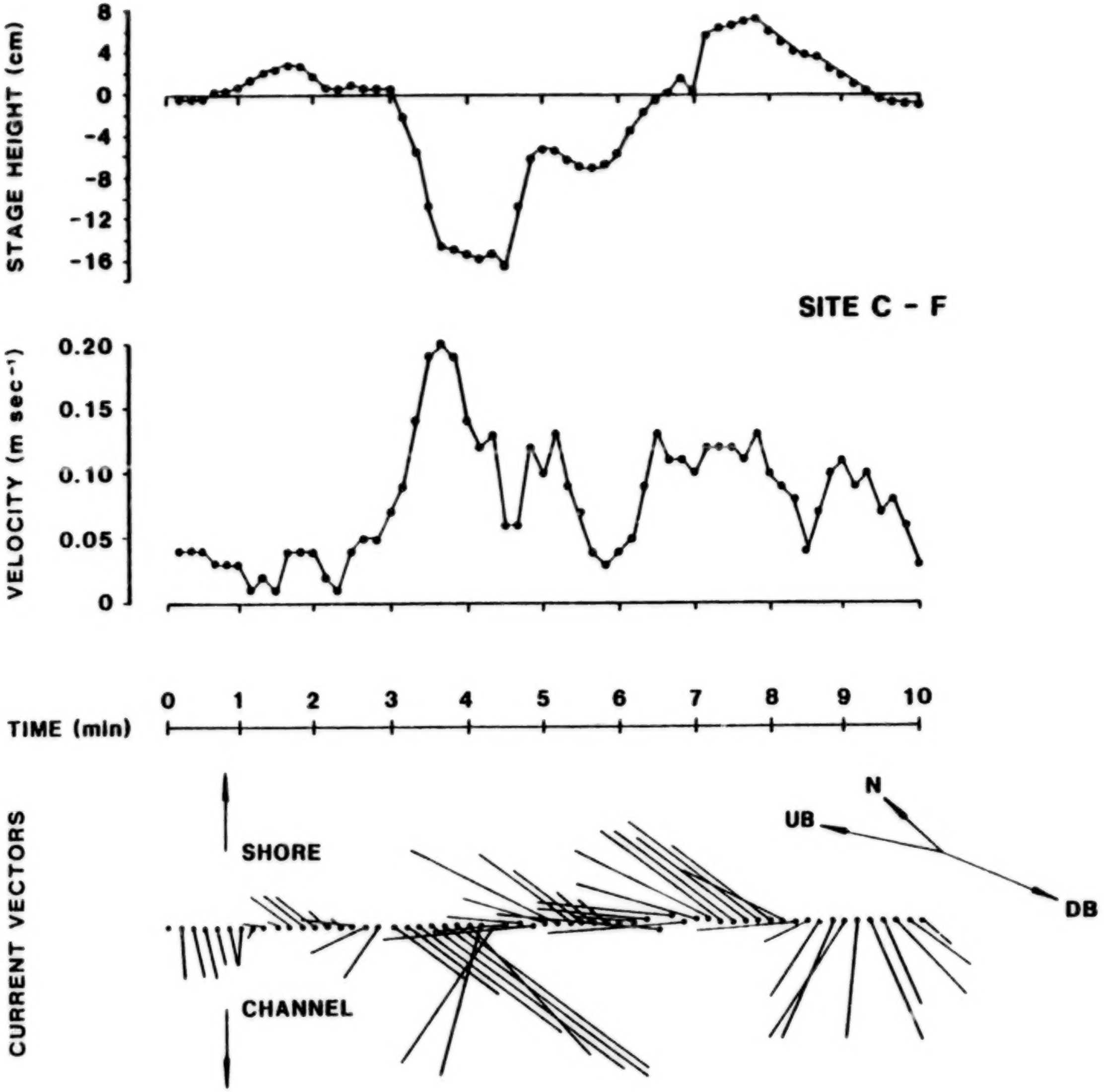

Figure 14. Water level changes and current vectors generated by the upbound passage of the Burns Harbor (Passage 11C-F of Table 7).

264

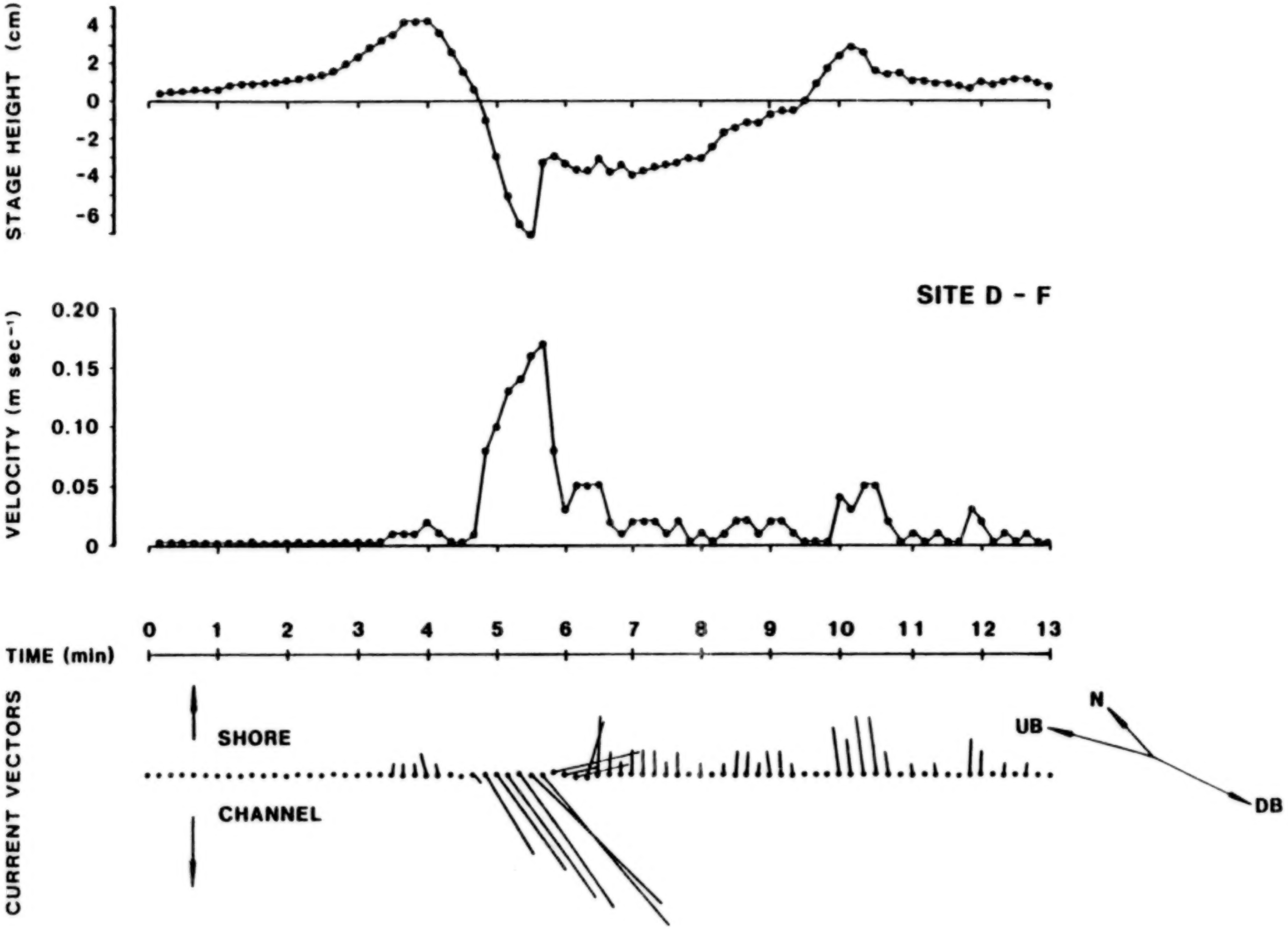

Figure 15. Water level changes and current vectors generated by the upbound passage of the Str. Comeaudoc (Passage 5D-F of Table 8).

265

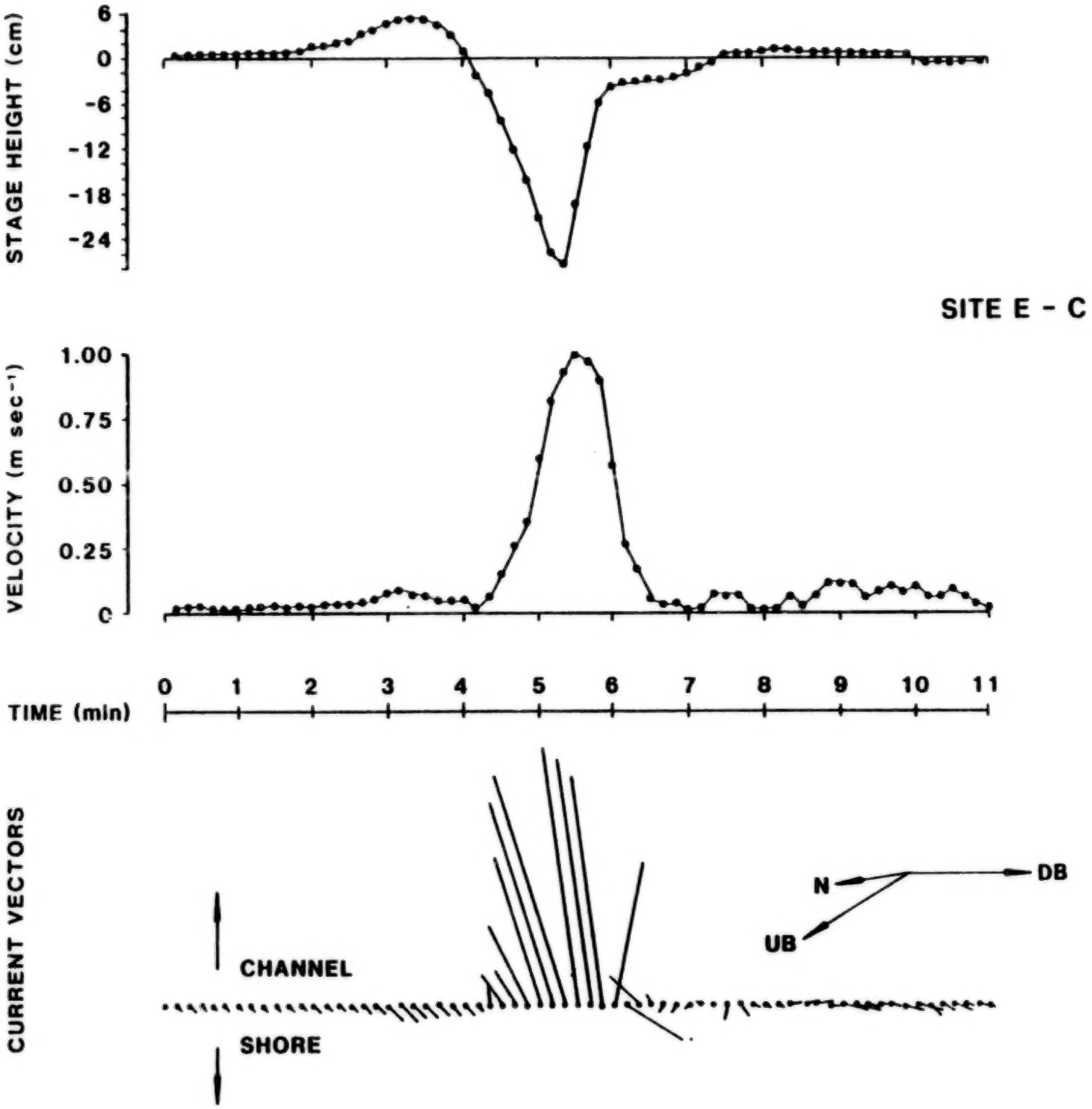

Figure 16. Water level changes and current vectors generated by the downbound passage of the Edward B. Greene (Passage 4E-C of Table 9).

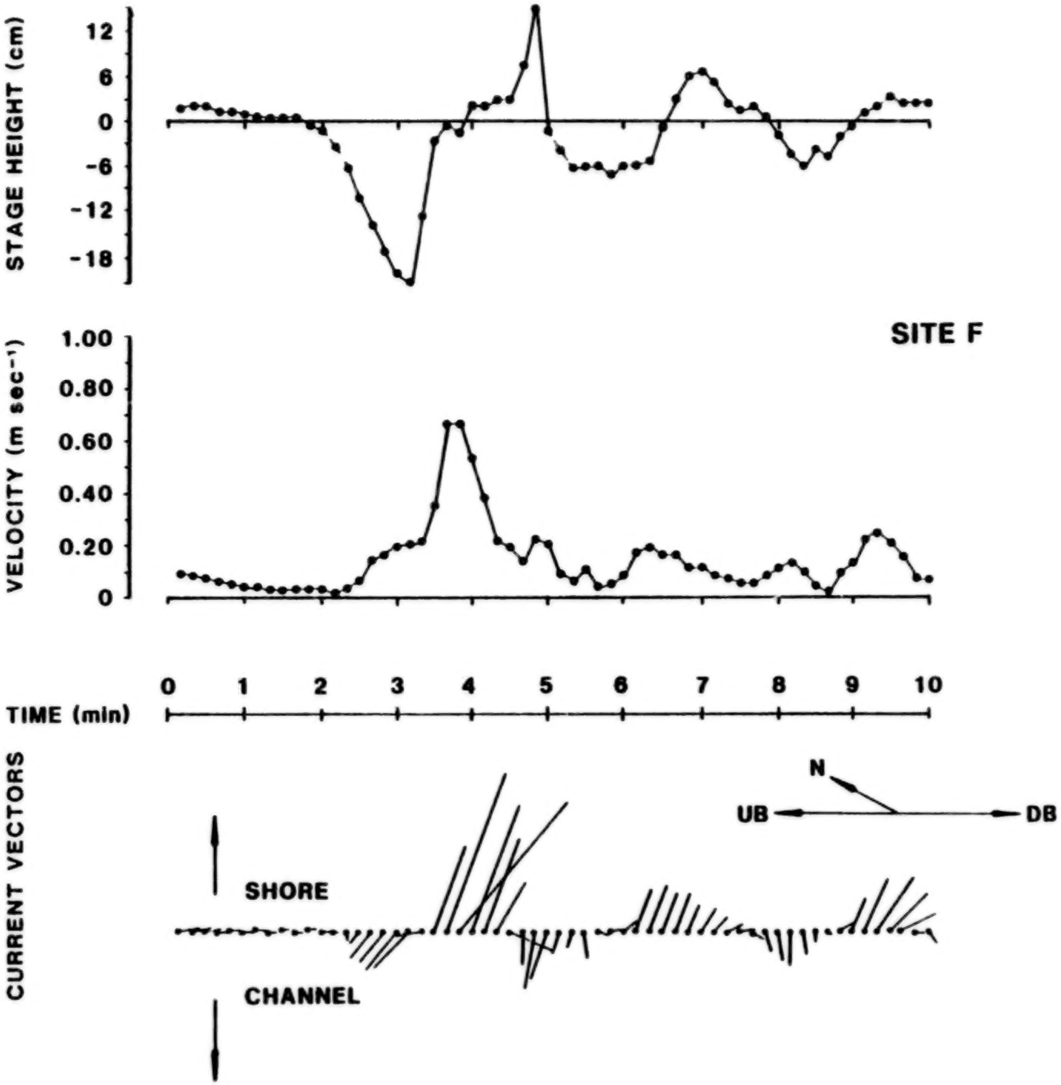

Figure 17. Water level changes and current vectors generated by the downbound passage of the Royalton (Passage 2F of Table 10). For this non-wetland site the baseline for the current vectors is oriented parallel to the shoreline.

267

The figures showing the water cycles have a number of components that are common to each. The uppermost portion of the drawing shows the median water level for each 10 second interval. Below that the 10 second mean current velocities are drawn. The time bar indicates the duration of the event in minutes. The bottommost portion of the drawing depicts current vectors. The dotted baseline from which these vectors originate represent the wetland face. In some instances the points of origin are moved slightly off the baseline so that consecutive vectors are not superimposed over one another. Arrows pointing to the navigation channel and the shore are generalized to indicate their approximate direction. The orientation of the wetland boundary in relationship to true north and both the upbound (UB) and downbound (DB) channels is indicated by the directional arrows found in the lower right-hand corner.

The discussion given below for the water cycle presented in Figure 11 is applicable, in a generic sense, to the other events that are depicted in Figures 12 through 17. However, it is important to note that the magnitude of the both horizontal and vertical scales differs from figure to figure. This is especially important in evaluating Figures 16 and 17 where vertical scales are appreciably greater than in the other figures.

The water cycle depicted in Figure 11 is for measurements obtained in a channelized area of Site B (protected shore, disturbed site) for the upbound passage of the Ashley Lykes (passage 10B-C in Table 4). From NOAA Chart #14883 of the St. Marys River, this wetland face is 1.54 km (0.96 mi) on a perpendicular to the mid-point of the upbound navigation channel in Lake Nicolet and 0.80 km (0.50 mi) to the downbound channel (see Table 15 below for distances to navigation channels for all sites). The Ashley Lykes has a length of 593 ft (181 m) and a beam of 69 ft (21 m). For this passage it had an amid-ships draft of 15 ft (4.6 m) and it was calculated to be traveling at 9.1 mph. Other measurements for this event are listed in Table 4.

Figure 11 shows the drawdown-surge cycle associated with this passage. The water cycle is divided into five phases. The phases, separated by dashed vertical lines, are shown only in this figure for purposes of illustration. Comparing stage heights in the upper portion of the figure to the data for water currents it can be seen that the first phase (initial) is characterized by little or no change in water level and ambient current velocities which for this event were zero. In the second phase (standing wave), the water level increased and current velocities were detected for the first time. The currents generated were flowing towards the shore. They reached a maximum velocity mid-way through the phase and then returned to zero. Drawdown began after the water level had returned to its baseline and velocities began to increase concurrent with a shoreward to channelward change in current direction. The greatest 10 second mean current velocity was noted in this phase: 0.20 m sec^{-1}. For other ship-passage events maximum 10 second mean current velocities were usually noted during this phase or during surge (see Tables 3 through 10 for the phase in which these maxima occurred). The drawdown continued until the current direction reversed itself and flow was directed back towards the shore. This reversal of flow began after the water level had reached its lowest point; this marked the beginning of the surge. Surge continued until current velocities diminished to almost zero and the water level neared the baseline. The final phase of the water cycle is denoted as post-passage. This phase is characterized by water level fluctuations around the baseline and current velocities that exceeded ambient conditions. It was during this phase that waves created by the wake of the passing ship crossed the sampling station.

As mentioned above, this cycle typifies water movements associated with ship-passage for all of the sites monitored during this study. Events at Site F deviated somewhat from this pattern as shown in Figure 17. Two probable causes for this deviation are: (1) there was no developed wetland at this site which could act to dampen the physical energy created by ship-passage, and (2) the channel is very narrow in this reach of river which might allow for the water to be reflected back from the opposite shoreline.

Figure 12 shows the water cycle for ship-passage 3B-F (Table 5). The sampling station was located at the face of the wetland at Site B. The ship Rimouski which created this water pattern was traveling in the downbound navigation channel. Vessel-passage water cycles at Site C are presented in Figures 13 and 14. Figure 13 is for an event (13C-C) measured in a channelized area of the wetland while Figure 14 is for an event measured at the wetland face (11C-F). Measurements for physical parameters for these events are found in Tables 6 and 7 respectively. Both events were for ships passing in the upbound channel. The sampling station at Site D was located at the wetland face; event 5D-F (Table 8) is depicted in Figure 15. Figure 16 is the water cycle that was generated by the downbound passage of the Edward B. Greene at a channelized area of wetland Site E (Passage I.D. 4E-C, Table 9). The final figure of a water cycle (Figure 17) was at the only non-wetland site, Site F. The ship that produced this pattern was the downbound Royalton (Passage I.D. 2F, Table 10). This is the same shipped that generated the water cycle depicted in Figure 13. However, for this event it was traveling in the opposite direction at a slower speed and was fully loaded.

Tables 3 through 10 indicate that the greatest impacts during ship-passage, in regard to water level changes and current velocities, occur most frequently during drawdown. Plots of values for these two parameters during drawdown versus vessel length, beam and speed for all events are shown in Figures 18 through 20, respectively. Vessel length, beam and speed were chosen since these are three of the parameters used by Wuebben (1983) in his model for ship-passage effects. Part A of each figure is for changes in stage height and Part B for maximum 10 second mean velocities. There is a marked similarity between Parts A and B for each figure. That can be explained by the fact that these two parameters are related to one another. Plotting velocity against change in water level during drawdown shows an apparent linear increase (Figure 21). The greater the displacement in the water level the greater the current that is generated as the water tries to re-equilibrate. To picture this, envision how the speed of a ball rolling along a plane surface becomes greater as the angle of the plane on which it is rolling increases.

Visual inspections of Figures 18 through 20 do not reveal any apparent trends. Ship size or speed have little or no correlation between changes in water level and current velocity when all events are pooled. Therefore, in attempt to better elucidate ship-passage impacts, events were segregated by direction of travel within a sampling location.

269

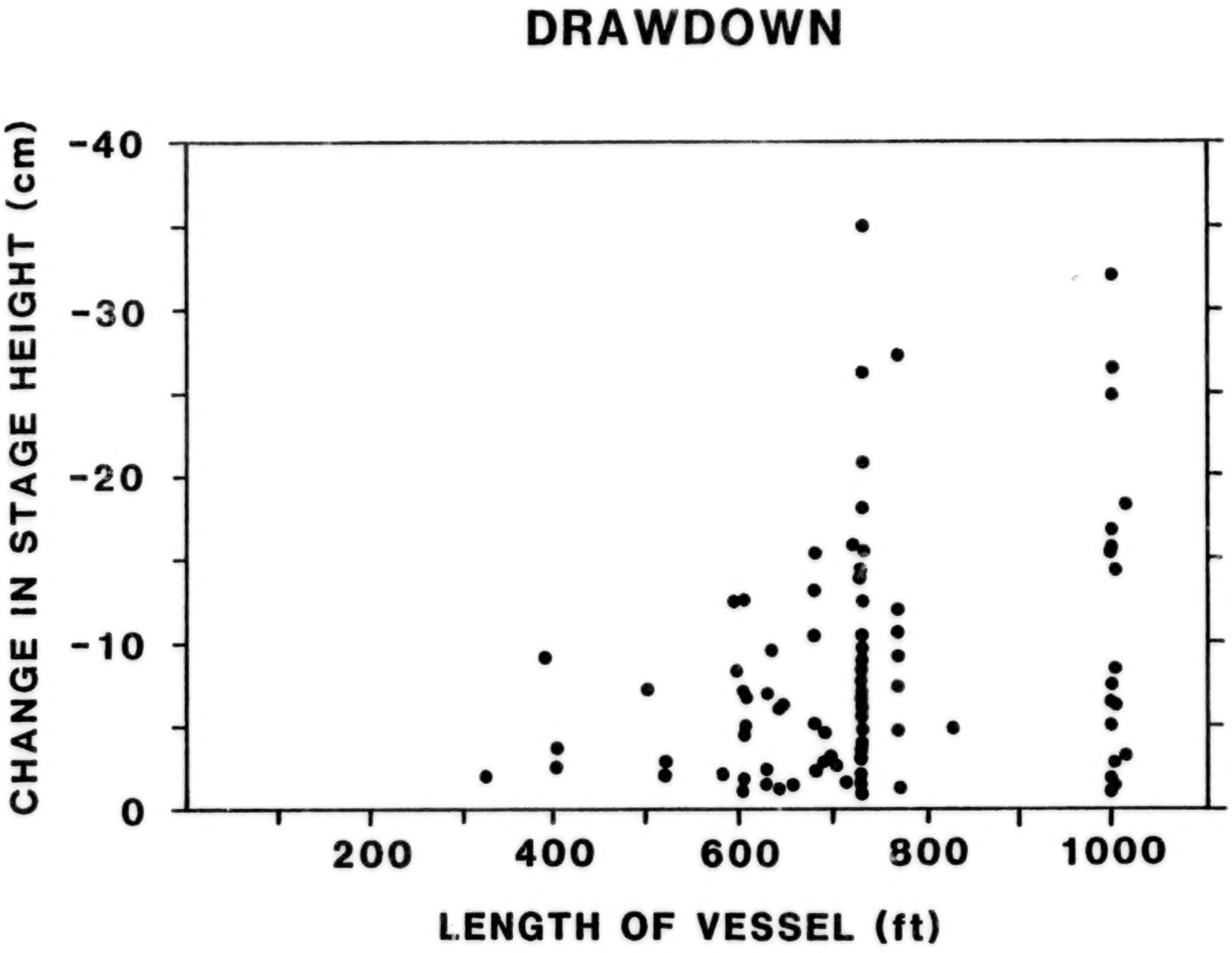

Figure 18A. Vessel length versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.

270

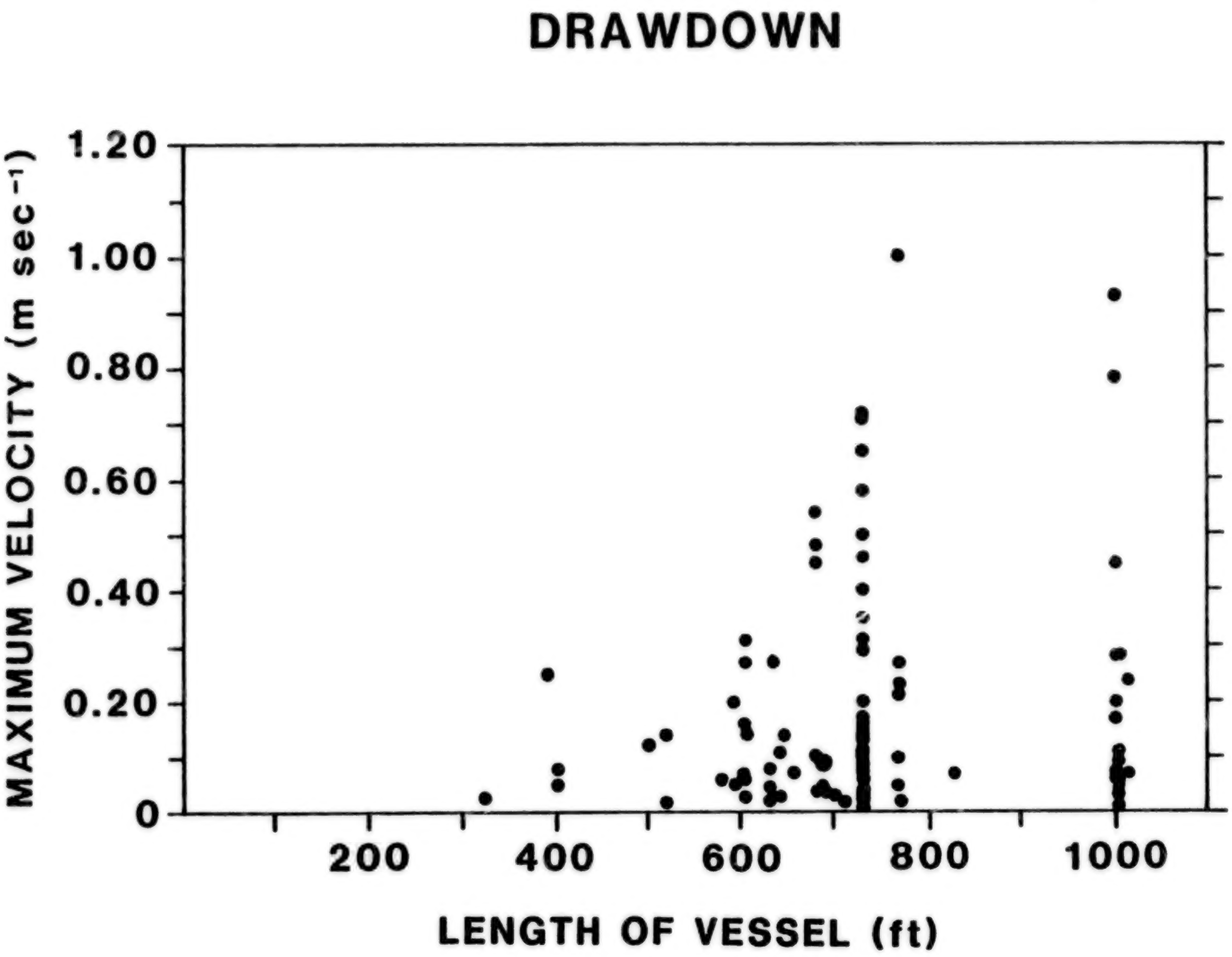

Figure 18B. Vessel length versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.

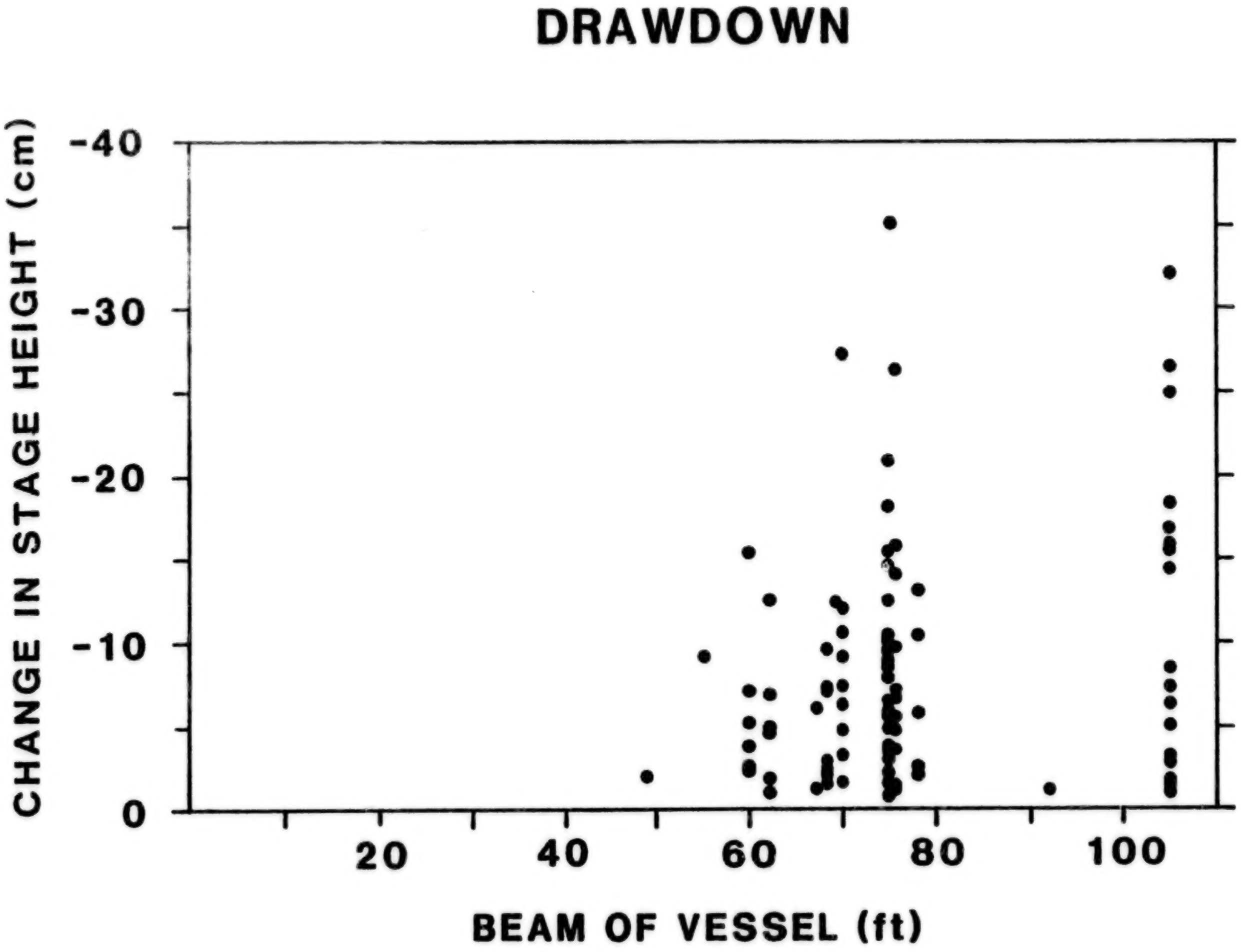

Figure 19A. Vessel beam versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.

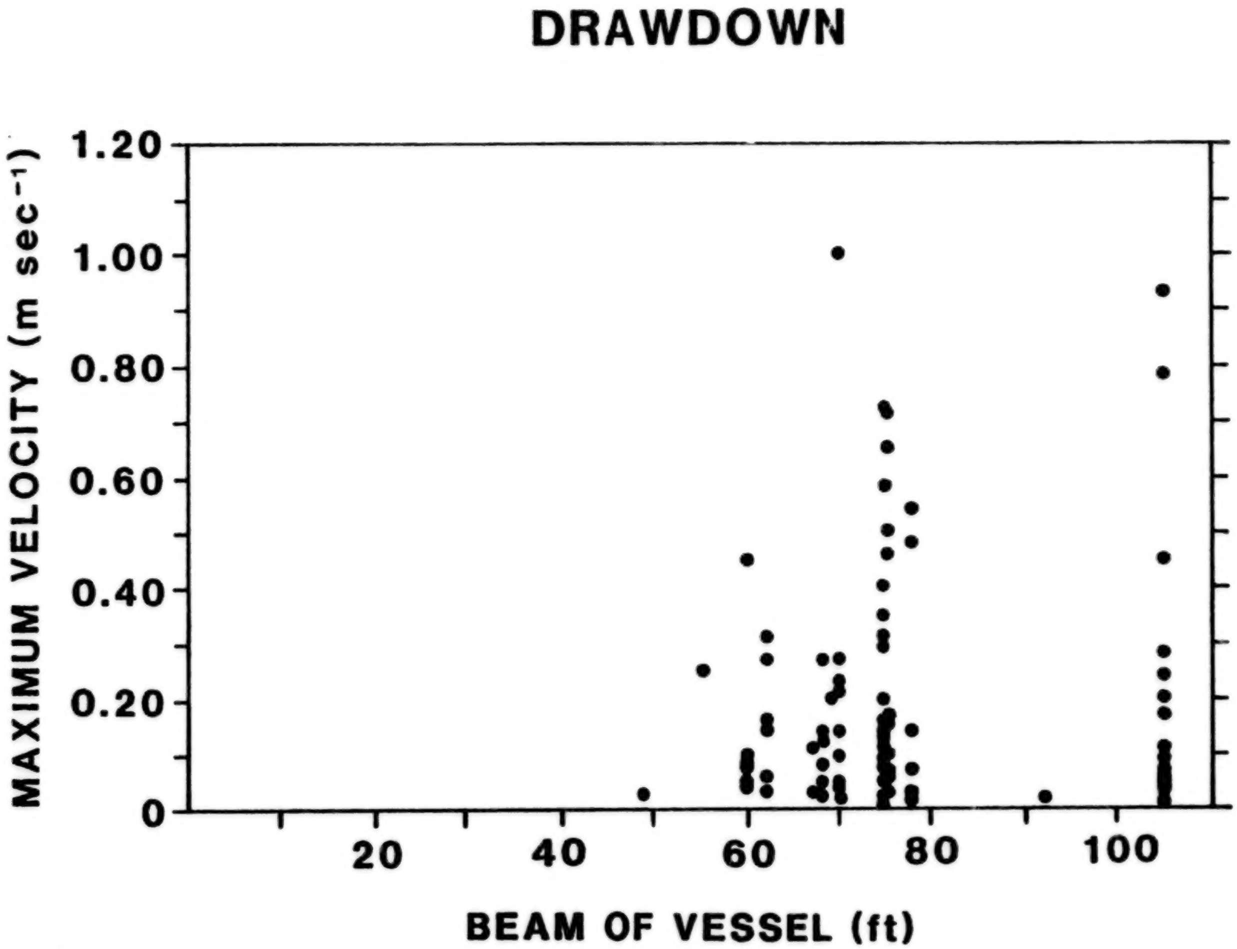

Figure 19B. Vessel beam versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River.

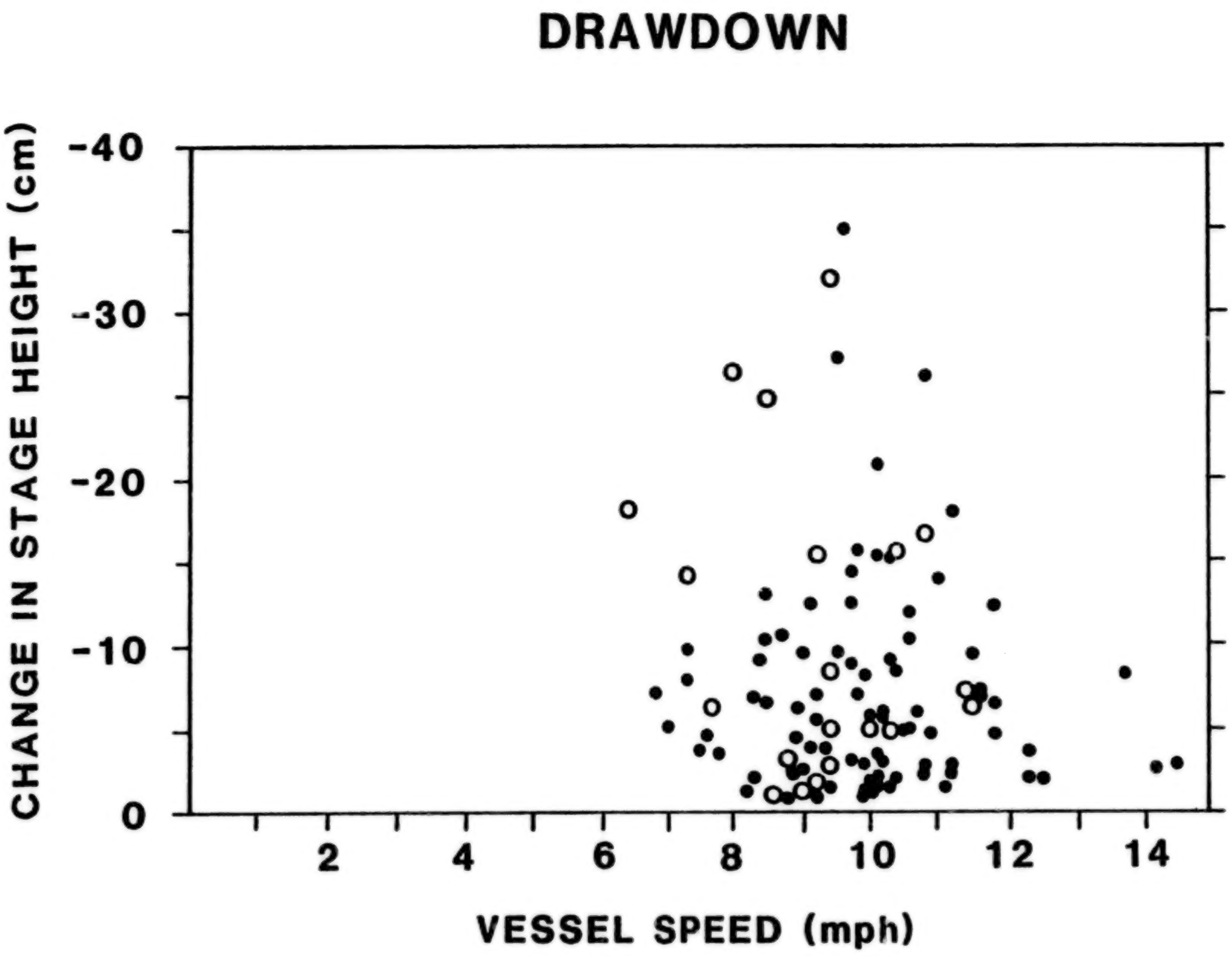

Figure 20A. Vessel speed versus maximum change in stage height observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.

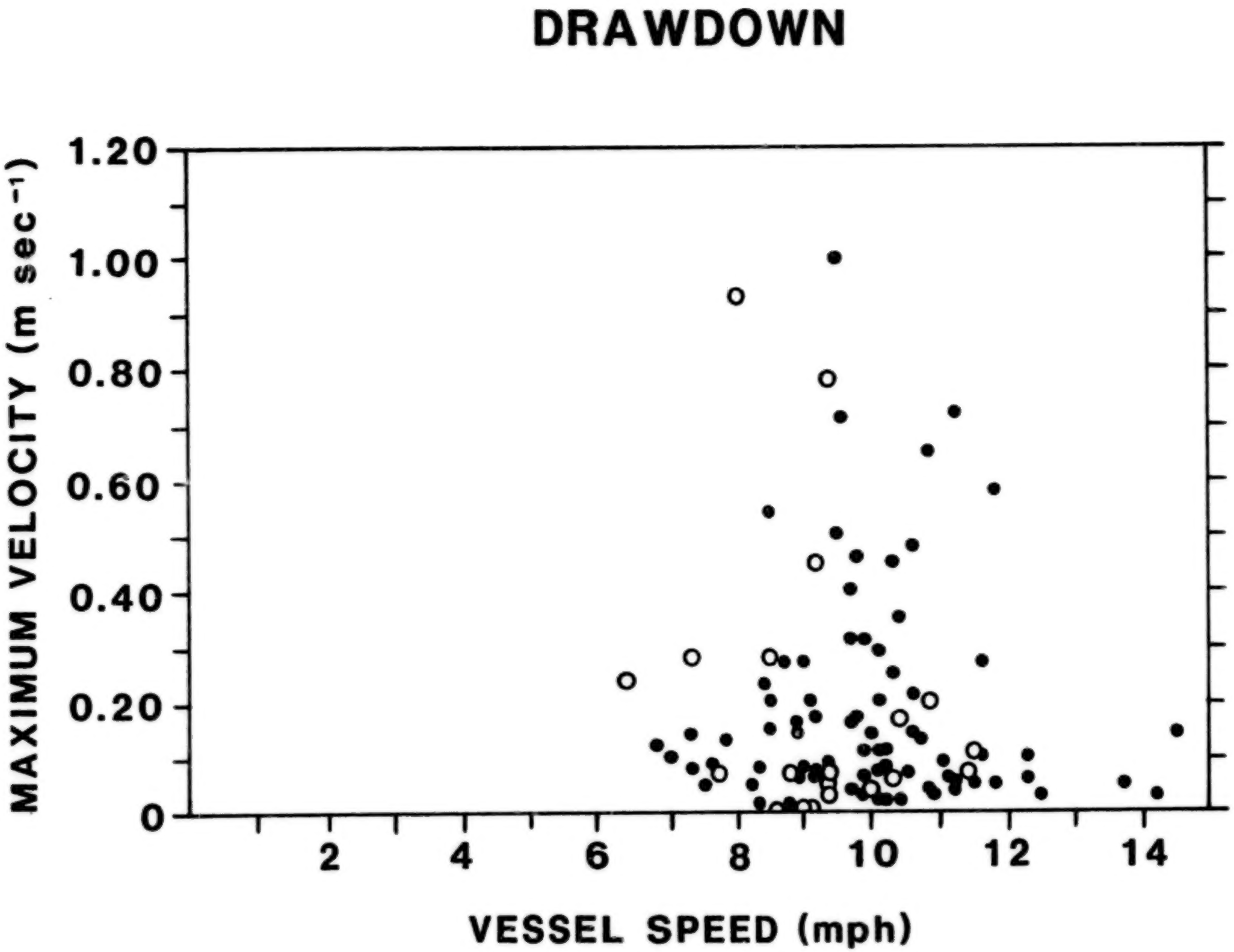

Figure 20B. Vessel speed versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.

BLANK PAGE

BLANK PAGE

BLANK PAGE

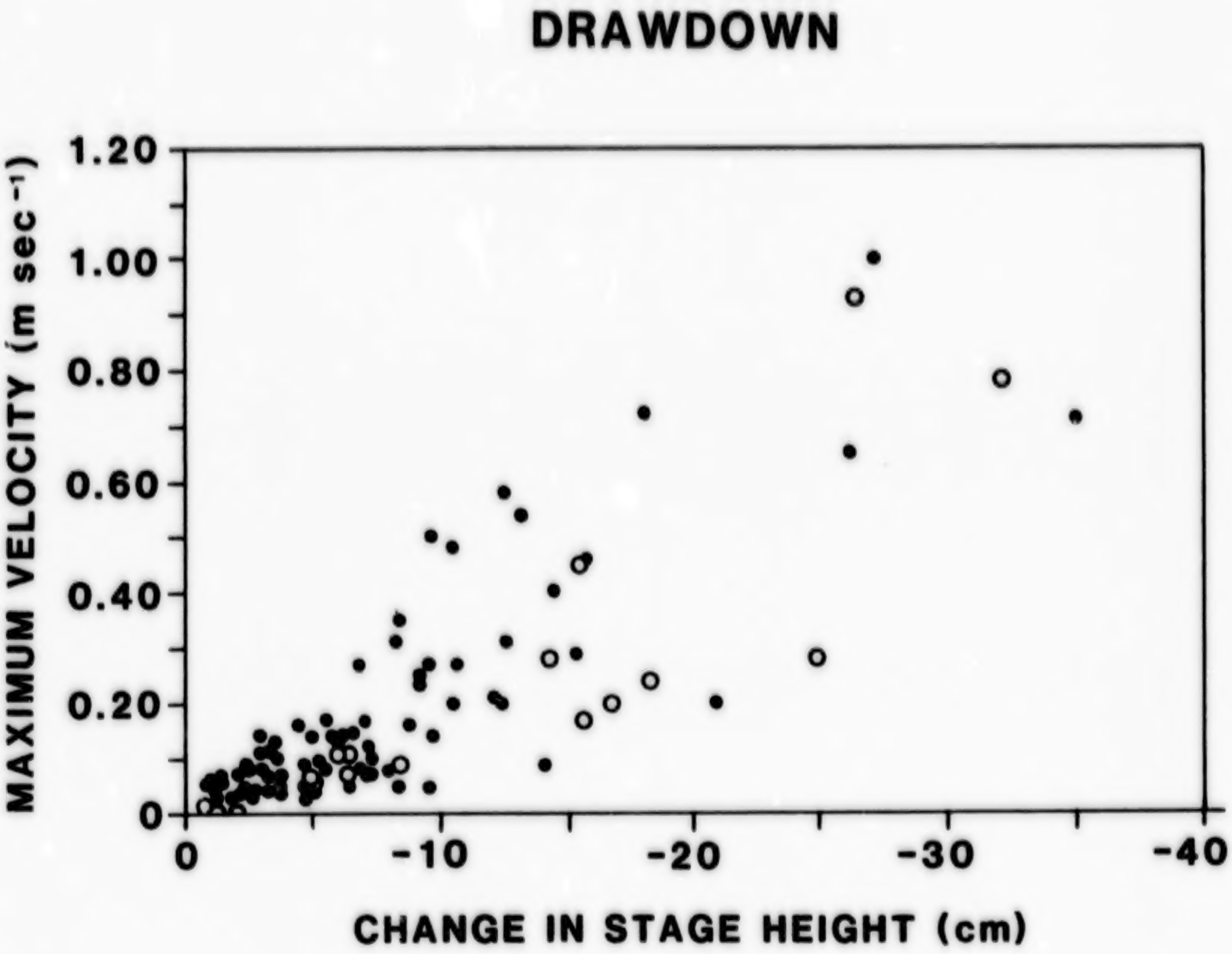

Figure 21. Maximum change in stage height versus maximum 10 second mean current velocity observed during drawdown for the 130 ship-passage events monitored during the open-water period of 1984 on the St. Marys River. Open circles represent values for ships that are 1000 ft by 105 ft.

Figure 22 shows maximum change in stage height (Part A) and maximum 10 second mean current velocity (Part B) during drawdown at each site for upbound and downbound vessels. For each sampling site, downbound events are shown on the left (represented by circles) and upbound events on the right (represented by triangles). Closed symbols represent the largest size class of vessels (1000 ft by 105 ft) while all other size classes are represented by open symbols. Figure 23 is similar to Figure 22 but represents measurements during surge.

It is apparent from these two figures that there is a great deal of variation in maximum changes in water level and current velocities both within and between sampling locations. In every case the range of values is greatest at each sampling site for a particular direction of travel: at Sites A-F, B-C, B-F, C-C, C-F, and D-F it is for upbound events while at sites E-C and F it is for downbound traffic. The first supposition might be that this is the result of the distance from the navigation channel to the sampling site; Table 15 lists these distances. At Site F both upbound and downbound vessels travel within the same navigation channel. However, there is a much greater range of values for changes in water level and current velocities during either drawdown or surge for downbound events. It is likely that at this site, vessel speed, not distance is more important in explaining the variability. Other factors must be involved since the event that produced the largest change in water level and the greatest current velocity was a ship traveling 9.4 mph, which is slightly less than the average ship speed (9.6 mph) of the downbound events. At Site B the greatest amount of variation occurred for upbound events. The distance from the wetland face to the upbound navigation channel is almost two times greater than the distance to the downbound channel. This would indicate that for this site distance is not the most important factor for predicting the effects of ship-passage.

Table 15. Distances from the sampling stations to the middle of the upbound and downbound navigational channels of the St. Marys River. For Sites A through E these distances were from the face of the wetland and perpendicular to it.

Site	Distance to Channel in kilometers	
	Downbound	Upbound
A	1.12	1.46
B	0.80	1.54
C	0.80	0.48
D	2.40	1.44
E	0.56	2.42
F	0.26	0.26

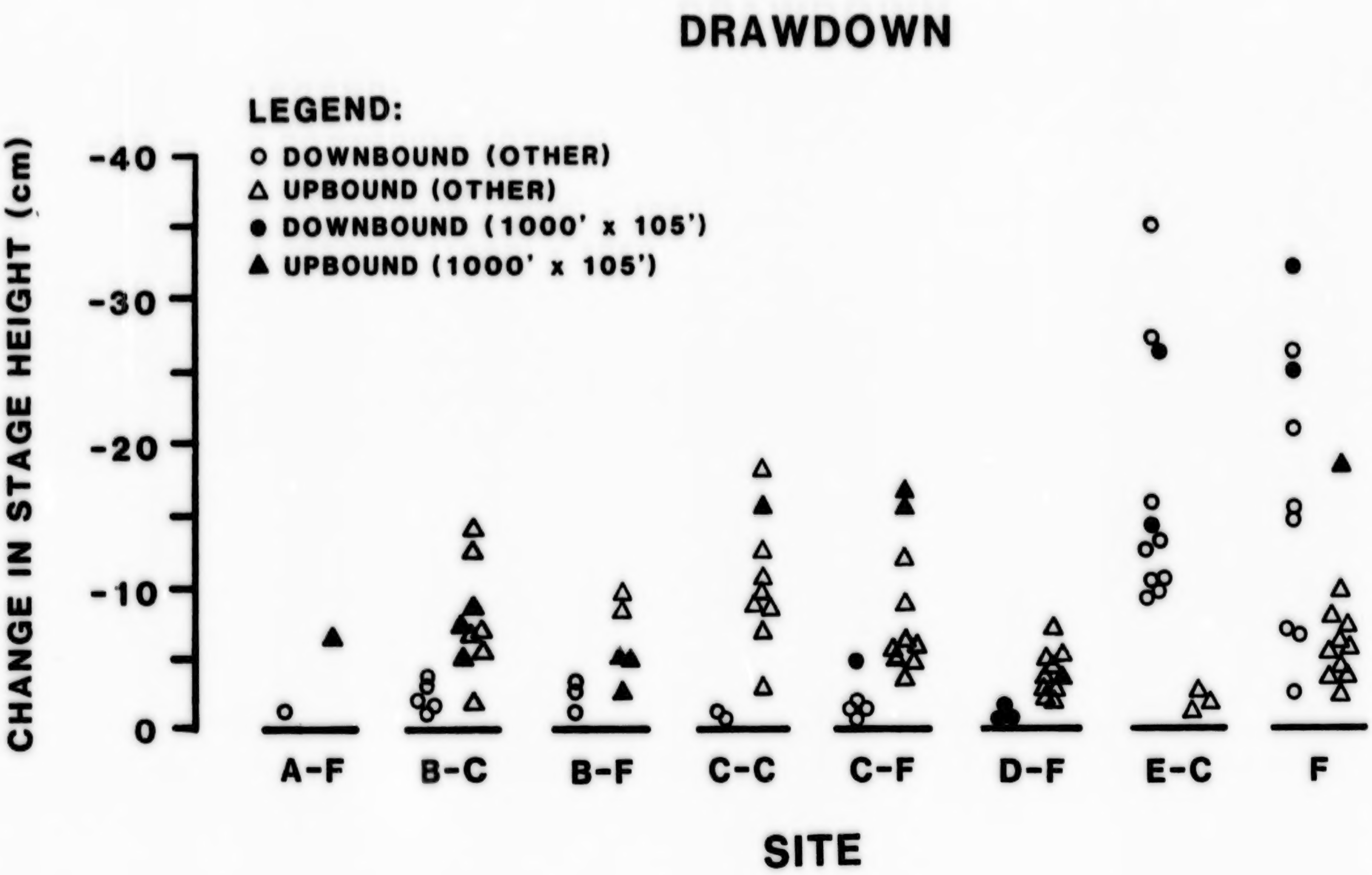

Figure 22A. Maximum change in stage height during drawdown for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.

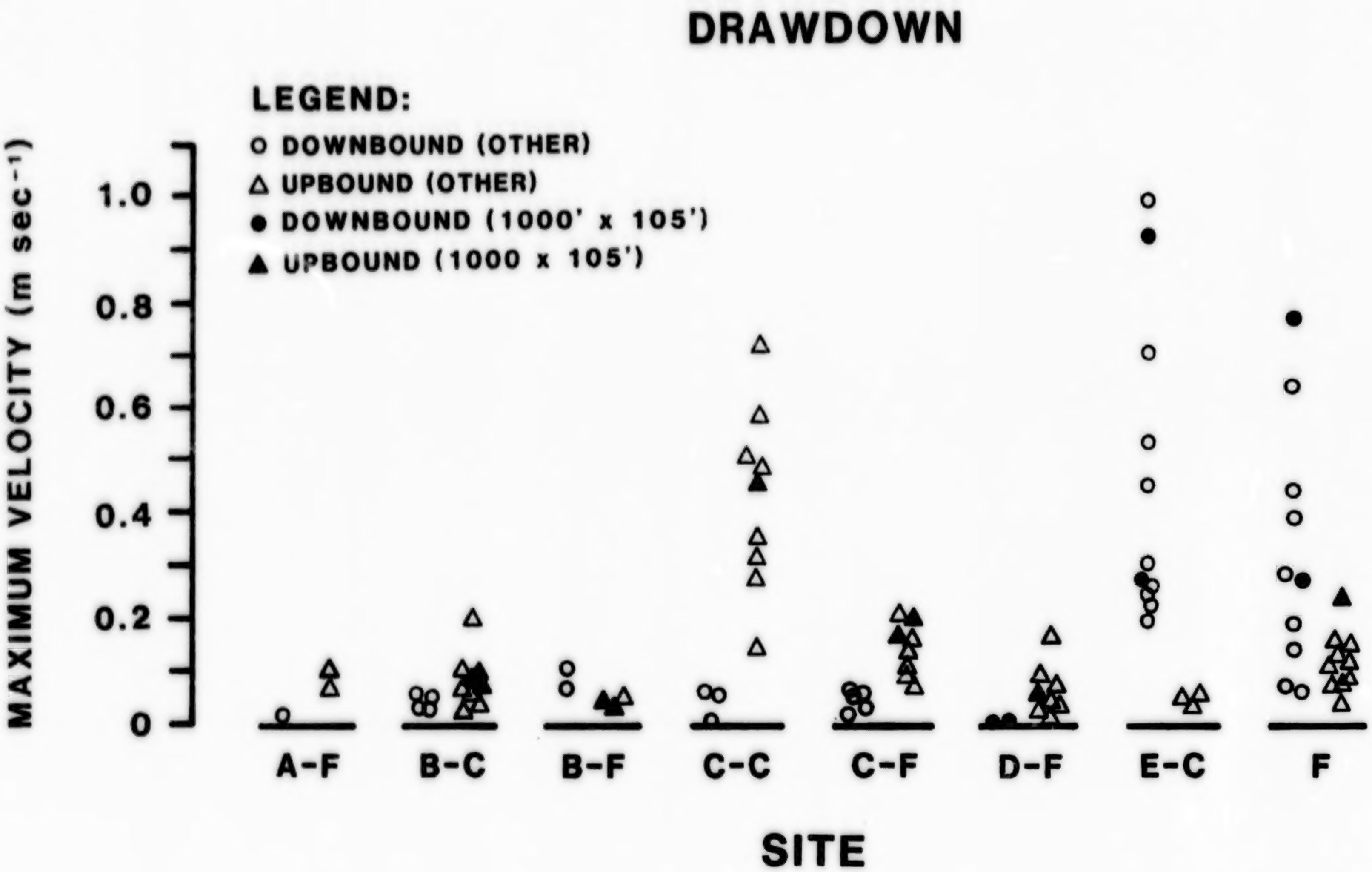

Figure 22B. Maximum 10 second mean current velocity during drawdown for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.

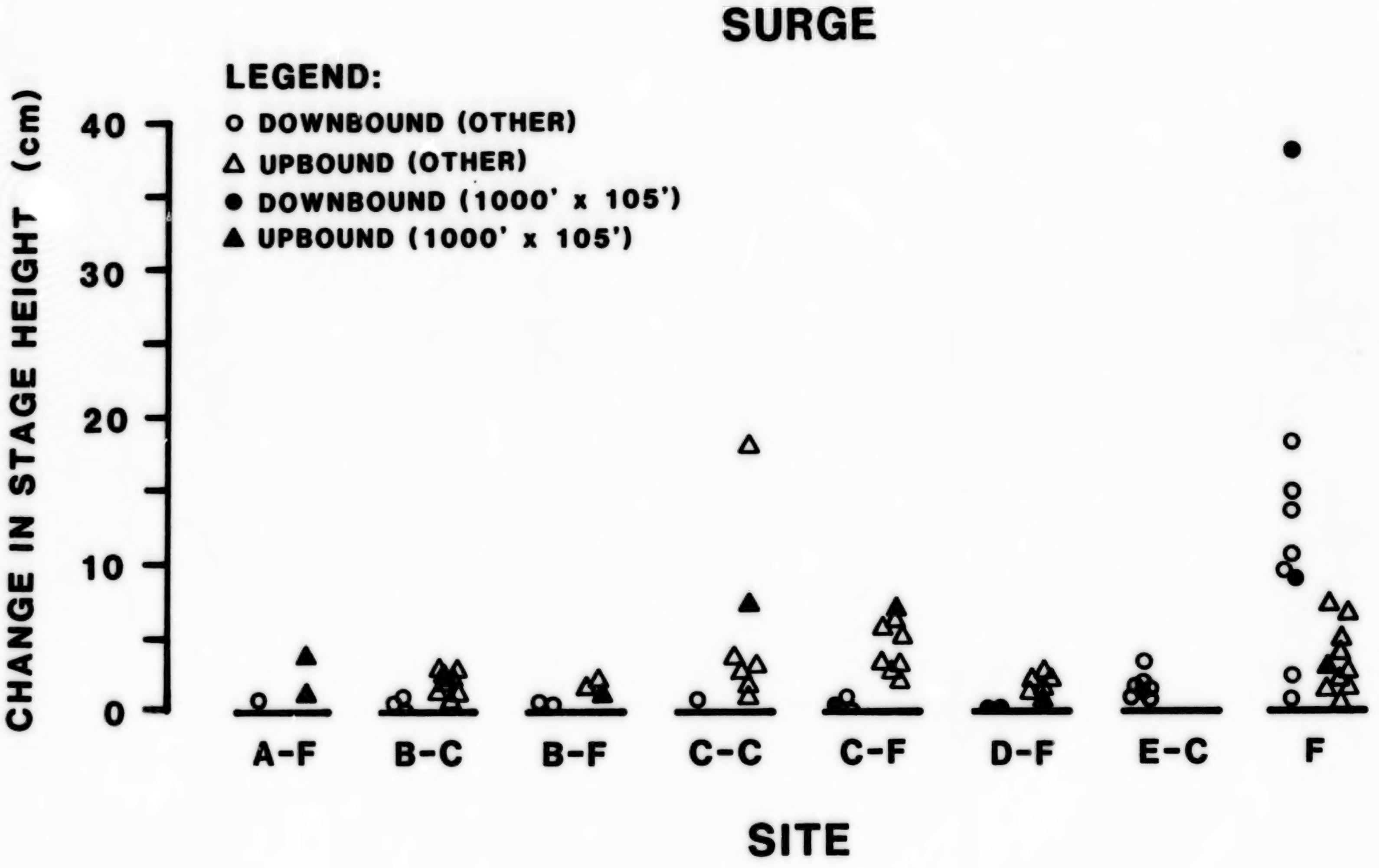

Figure 23A. Maximum change in stage height during surge for each sampling site for all events monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.

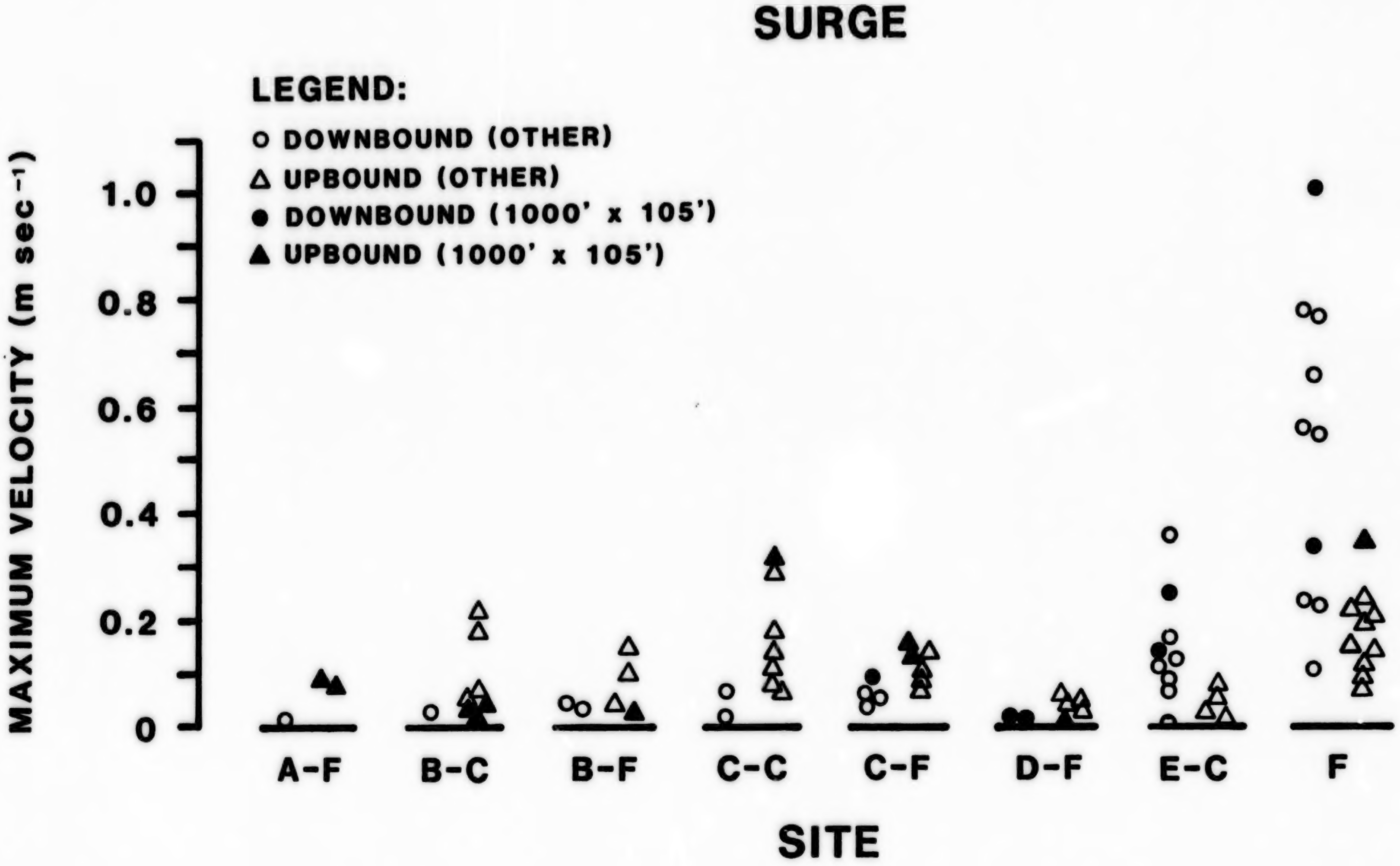

Figure 23B. Maximum 10 second mean current velocity during surge for each sampling site for allevents monitored during the open-water period of 1984 on the St. Marys River. The direction of vessel travel is separated within a site.

At Sites B and C two sampling stations were established: one at the face of the wetland, the other in an open area of channelization. Figures 22 and 23 show that for these two sites there is a greater range of values both during drawdown and surge for the channelized sampling stations. This suggests that the vegetation might ameliorate the impacts of vessel-passage.

Regardless of the causal mechanisms for changes in water level and current velocities during ship-passage, wetlands in many reaches of the St. Marys River are affected by these events as indicated by the results of this study. The magnitude of the impact is dependent on the location of the site. Table 16 presents the vegetational status of the wetland sites that were monitored for this study during the open-water period of 1984. The vegetational status was based on work that was done previously (Liston et al. 1986). The table also shows both predicted and observed changes in water level during drawdown. Predicted values are from Wuebben (1983); they were derived from the model for the passage of a 1000 ft by 105 ft ship traveling the speed limit and having a draft of 25.5 ft. The observed drawdown is for the range of values measured during this study. The final two columns were calculated from the drawdown values and the bathymetric maps. The depth contours for each of the bathymetric maps were drawn relative to a river stage height of 176.693 m (579.70 ft); this facilitated comparison between sites. Depth contours corresponding to the predicted and maximum observed drawdown values were superimposed onto these maps; areas of the wetland confined by the shore and these boundaries were then determined and compared to the area of the wetland as a whole. Areal values are expressed on a percentage basis since the areas of wetlands mapped varied from site to site.

Table 16. Vegetational status of selected wetland sites of the St. Marys River, predicted and maximum observed drawdown, and calculated areas of wetland exposed for those levels of drawdown.

Site	Vegetation Type	Vegetation Pattern	Drawdown		Calculated Area Exposed	
			Predicted[1] (m)	Maximum Observed[2] (m)	Predicted (%)	Maximum Observed (%)
A-F	Most-Protected	Undisturbed	0.06	0.06	<1	<1
B-C	Most-Protected	Disturbed	0.39	0.14	10	2
B-F	Most-Protected	Disturbed	0.39	0.10	10	2
C-C	Least-Protected	Disturbed	0.29	0.18	40	15
C-F	Least-Protected	Disturbed	0.29	0.17	40	15
D-F	Least-Protected	Undisturbed	0.20	0.07	15	6
E-C	Most-Protected	Disturbed	0.49	0.35	95	58

[1] From Wuebben (1983) for 1000 ft (305 m) vessels.

[2] From ship-passage events monitored during the open-water period of 1984.

Table 16 shows that except for Site A-F, the calculated areas of wetland exposed for maximum observed drawdown were always less than those for the predicted drawdown. Either the predicted values of Wuebben (1983) over-estimate the effects of drawdown or none of the vessel-passages that were monitored during this study met the criteria used in the model. Data presented in Tables 3 through 10 show that of the 23 events for ships that were 1000 ft by 105 ft, none had drafts 25.5 ft or greater and were traveling equal to or greater than the speed limit. Therefore, no assessment as to the validity of the model can be made. However, that was not the intent of this study. Consistent with purposes of our work, baseline data regarding hydrologic effects of ship-passage on wetlands of Lake Nicolet have been presented.

Movement of sediments and several parameters in water were measured in this study during ship-passages. Samples for this work were collected near outer edges of wetlands at stations used for measuring hydrologic changes during passage. Samples of sediments and water were obtained for a series of passages where current directions during passage were like those of Figures 12, 14, and 15: namely, into wetlands during standing waves, out of wetlands during drawdowns, and into wetlands during surges. Ship-passages with these current directions were chosen from among current directions patterns observed in this study so that net exchange of materials between wetlands and the river during drawdown and surge could be measured. Parameters measured in water put in motion during passages were chlorophyll a, organic carbon, and residues left on evaporation. These were chosen to assess net exchange of algae (chlorophyll a), organic food materials in general including algae (organic carbon), and dissolved materials including nutrients (dissolved residues) between high-production and low-production plankton communities in the river itself. This study of movement of materials was exploratory in nature, that is, aimed at obtaining baseline data on processes that might be worthy of further investigation. Data from this work have been presented in Tables 11 and 12.

Wuebben (1983) used sediment traps to describe directions of movement of sediments as a result of ship-passages on the St. Marys River. Similar traps were used in this study at edges of wetlands during late-July and August when wetland vegetation was well developed. Traps were set so that they were open in four directions to movements of sediments along the bottom: parallel to edges of wetlands in upriver and downriver directions, toward wetlands, and toward the river at right angles to outer boundaries of wetlands. Samples were taken for intervals of no offshore vessel-passage (ambient samples), and for intervals in drawdown-surge cycles during passage. Reliability of data gathered suffers from lack of replication in samples obtained during this exploratory work. It is important to note that variability in data from sediment traps, as well as variability in parameters measured in the water except as discussed below, was not explained by regression analyses where measurements of water movements (e.g. current velocities and changes in water elevation of Tables 4 through 9) made in conjunction with sediment and water chemistry measurements were used as independent variables. However, a number of patterns exist in the data that are worthy of consideration.

Results with sediment traps showed that those set under ambient conditions of water movement served as deposition sites for sediments regardless of their orientation. Sediment deposition under ambient conditions varied

283

among sampling sites, being higher at Site B, than elsewhere. Averaged data from a total of 19 ship-passages unevenly distributed among four sites along the river showed net deposition (passage sedimentation minus ambient sedimentation) in traps open in the upriver direction. An average of 0.30 g dry weight of sediments accumulated per passage in these traps. Net deposition also occurred in traps open in the downriver direction: on average, 0.25 g dry weight per passage. Data in downriver traps at Site B had a high frequency of negative net deposition values, indicating net export from them in the downriver direction during ship-passage. In averaged data from nine ship-passages at Site C, net deposition in traps open downriver slightly exceeded net deposition in traps open upriver. These results from Sites B and C illustrate site specificity in regard to sediment transport. Means taken for the data set as whole suggest that ship-passage causes a downstream movement of sediments along edges of wetlands.

Perusal of data from sediment traps open in the direction of wetlands shows that sediments tend to move away from wetlands during ship-passage. on average, 0.11 g dry weight net sediment deposition occurred in these traps at four study sites. This mean was low relative to means for traps open in other directions. Traps open to the river at right angles to edges of wetlands accumulated an average of 0.29 g dry weight of sediments. A comparison of means from traps open to the wetlands and the river suggests that at positions in which traps were placed, namely at edges of wetlands, there is a net movement of sediments toward wetlands. Whether sediments deposited in traps open to the river at right angles to wetland edges actually are transported into wetlands is unknown from this work. However, data gathered suggest that wetland plants partially stabilize shorezone sediments during ship-passage. Sediment transport in a direction outward from wetlands was on average only 37-44% of transport in other directions during ship-passage.

Chlorophyll *a* was used in this study as a measure of algal biomass suspended in the water at sampling sites. Samples were taken at each site prior to monitored ship-passage events to determine background concentrations of algal biomass. For ship-passage events, composite samples were made up for standing wave, drawdown, surge, and post-passage intervals. Data from these samples showed differences between sites in regard to background algal biomass: mean chlorophyll *a* was higher at wetland edges at Sites B and E on the west shore of lake Nicolet (1.07 ug 1^{-1}) than at Sites C and D on the east shore (0.64 ug 1^{-1}). Site B also differed from Sites C and D in regard to changes in algal biomass between background samples and those taken during ship-passage wave cycles. Algal biomass increased in water at Site B during one or more wave phases of each of seven monitored ship-passage events, indicating recruitment of suspended algae from the periphyton or the sediment surface. Mean background concentrations of chlorophyll *a* at Site B were 1.03 ug 1^{-1}, while mean concentration for the intervals of wave movement across the site, as well as for the post-passage interval, was 1.15 ug 1^{-1}. While ship-passage had the effect of recruiting algae into the water column at Site B, perusal of the data does not suggest a similar effect at Sites C and D. Site E was not considered in this regard because data for only a single ship-passage exists for that site. Information regarding food webs in the St. Marys River system is not sufficiently developed to speculate on the ecological significance of increased algae recruitment in water columns of wetlands as a result of ship-passage.

Liston et al. (1986) have shown that emergent wetlands of the St. Marys River are areas of high food production (plant and invertebrate production) relative to the oligotrophic plankton community of the river. Casual observation of drawdown-surge cycles in wetlands suggests that one effect of ship-passage might be to enrich the plankton community with food, and perhaps plant nutrients, by way of export from wetlands during drawdown. Sampling for chlorophyll *a* and organic carbon as indices of food, and dissolved residues as an indicator of plant nutrients, was conducted in this study such that net exchange of these materials across wetland faces could be detected during ship-passage, if transport in one direction was large relative to transport in the other direction. To examine net exchange, exporting currents were sampled during drawdowns and importing currents during surges. Perusal of resulting data (Tables 11 and 12) shows that net exchange of algal biomass (chlorophyll *a*) across outer wetland boundaries at sites of measurements was essentially zero. Concentrations in water during drawdown were essentially the same as those in water during surge. The same was found to be true for total organic carbon. Thus, with methods used, wetlands did not appear to export foods to the river during the summer period when sampling was conducted. However, this study did not address exchange of particles with high specific gravity like plant fragments, macroinvertebrates, and larval fish. These may be carried out of wetlands during drawdown and escape returning surge currents by dropping out to the river bottom.

Unlike the zero net exchange for chlorophyll *a* and organic carbon observed during drawdown and surge, the trend in dissolved residue data suggests net import from the river to wetlands during ship-passage. For 19 passage events on four sites along the river, mean dissolved residue concentrations in drawdown water and surge water were 100.5 and 104.3 mg l^{-1} respectively. The difference between concentrations in drawdown and surge water given by these means is strongly influenced by measurements made at Site C for nine ship-passages. Unlike other sites where multiple measurements were made, concentrations in surge water at Site C always exceeded concentrations in drawdown water. Means for dissolved residue in drawdown and surge water were 101.6 and 106.6 mg l^{-1} respectively at Site C. These data suggest that, at least at some locations along the river, surge water is enriched is dissolved residues relative to water leaving wetlands during drawdown, and at these locations, there is a net import of dissolved residues, likely including plant nutrients, into wetlands during ship-passage. Several conditions to explain this observation come to mind.

Shoreward portions of emergent wetlands along the St. Marys River are known by us and others to be fed by water from seepage and/or springs. Dissolved residue concentrations in water thus input to the wetlands are unknown, but if they were low relative to offshore water, water in wetlands would be dilute relative to offshore water. Data from this study suggest that wetland water can be relatively dilute: mean background concentration at the outer boundary of the wetland during ship-passage measurements at Site C was 104.5 mg l^{-1} of dissolved residue, while drawdown water exiting the wetland had a mean concentration of 101.6 mg l^{-1}.

In the absence of significant influence due to seepage and springs, there are at least two ways that water offshore of wetlands could be enriched in dissolved residues relative to water in wetlands. One of these has to do with high dissolved residue concentrations in plumes of upstream domestic waste discharge that may pass along edges of wetlands in cells of water circulation that are relatively independent from low residue cells derived from offshore water and circulated through wetlands at particular sites along the river. Enriched plumes would need to be local, nearshore phenomena. Mean dissolved residue concentration observed by us in offshore channels of the St. Marys River in Lake Nicolet during this study was low: 98.0 mg l^{-1}. Thus two relatively independent cells of water circulation, one from the mainstem of the river perfusing wetlands along shore, and another enriched local cell moving along outer wetland boundaries at the same time of ship-passage could explain the observed net transport of dissolved residue into wetlands during this study.

Secondly, the work of Glandon (1982), and others that he cites, offers an explanation for observed dissolved residue exchange at outer boundaries of wetlands along the St. Marys River during ship-passages. His work deals with equilibrium abundance of sorbed ions on sediment particles while particles reside in sediment and suspension phases in aquatic systems. The general case, taken from his work, is that sorbed ions are abundant on particle surfaces while particles reside in sediments where pore water concentrations of ions are well known to be much higher than concentrations of the same ions in overlying water. When sediment-water systems are disturbed such that sediment particles are put into suspension, ions exit sediment particle surfaces to move the new suspension toward equilibrium in terms of sorbed and dissolved phases. An increase in dissolved residue concentration in the suspension ensues. For the case of wetlands at hand, application of Glandon's work requires the assumptions that surface sediments are perfused or suspended at current velocities of drawdown and surge, that ions sorbed to sediment particles are abundant enough to have a significant influence on dissolved residue concentrations in water during drawdown and surge (Glandon showed this to be the case for lake sediments that he studied), and that wetland sediments are nutrient-poor relative to sediments immediately offshore of wetlands. Given these as acceptable assumptions, Glandon's work explains why one should expect water exiting wetlands during drawdown to be poor in dissolved residues, and water returning to wetlands during surge to have high concentrations relative to drawdown water.

A relationship between differences in dissolved residue concentrations in drawdown and surge water for ship-passage events at Site C, and changes in water level during these events, is shown in Figure 24. The regression shown infers that as volumes of water involved in drawdown and surge increase (i.e. change in water level becomes large), the differences in residue concentrations during drawdown and surge increase. The coefficient of determination ($r = 0.91$) shows that there is good correlation between these two parameters. Of the three explanations offered above for observed enrichment of wetlands with dissolved materials during ship-passage, only that from Glandon's work includes large reserves of residues, namely those in offshore sediments, that can be dissolved in water and cause differences during drawdown and surge.

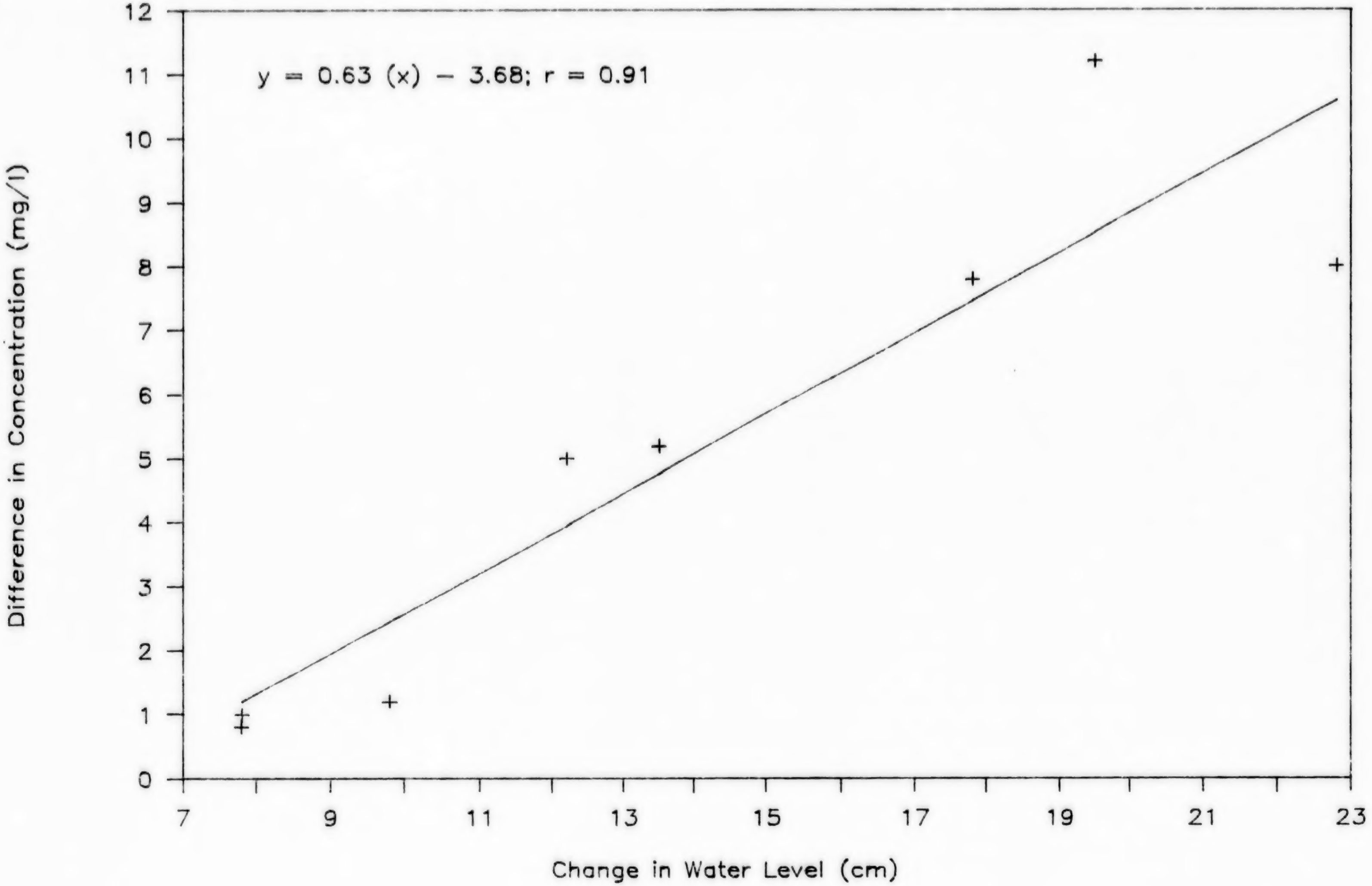

Figure 24. The relationship at Site C between differences in dissolved residues in water during draw-down and surge and changes in water level in the St. Marys River during ship-passage events of the open-water period of 1984.

SUMMARY

This study collected baseline data regarding hydrologic and certain biological and chemical effects of ship-passage on emergent wetlands of the St. Marys River. For measurements made between May and September 1984, the hydrologic influence of vessel-passage on emergent wetlands was passage specific. Differences in water level changes during drawdown and surge, and differences in current velocities in wetlands associated with vessel-passages, were not explained by any one independent variable measured in this study. Vessel length, beam, draft, hull design, speed, and direction of travel, as well as distance of the travel path from wetlands and morphometry of the basin traveled all appear to contribute to differences in hydrologic changes that occur in wetlsnds during passages. Drawdown during passage dewatered portions of wetlands. Instances were observed here where as much as 58% of sediment surfaces in wetlands were exposed during drawdown. The impact of dewatering on resident aquatic organisms in the St. Marys River will vary from season to season, and has not been quantified.

Measurements of sediment movements and concentrations of several materials in water were made for selected ship-passages where currents at sampling points during drawdown moved out of wetlands toward the river, and currents during surge moved from offshore in the river into wetlands. Sampling points were at outer edges of wetlands. In 19 measurements of sediment movements made in summer when vegetation in stands was well developed, ship-passage in each case caused sediments to move in each of four measured directions at rates in excess of non-passage rates. In general, net transport of sediments during passages was from the river toward the wetlands, and in the downriver direction as well. Ship-passage caused sediments to move out of wetlands, but at rates less than those for sediments moving inward from the river or parallel to the edge of the wetland. These data suggest that emergent wetlands partially stabilize shorezone sediments during ship-passage.

Chlorophyll *a* was used as a measure of biomass of algae suspended in water sampled during this study. During each of seven monitored ship-passage events on one site, algae increased to greater than background concentrations in water at the edge of the wetland. These algae were apparently lifted from periphyton and benthic communities on currents generated by passages. A similar increase was not observed at other sites where measurements were made. Data on producer-consumer relationships in food chains of the St. Marys River are not adequate to address ecological significance, if any, of site-specific suspension of algae during ship-passage. Data collected during 19 drawdown-surge cycles on four sites showed there was no significant exchange of suspended algae or other suspended or dissolved organic food materials between wetlands and the river during ship-passage.

Movement of water during ship-passages tended to enrich wetlands along the St. Marys River with dissolved residues (filtrate residue on evaporation). For nine ship-passages monitored at one site, concentrations of dissolved residues in drawdown water exiting the wetland was always less than concentrations in surge water re-entering the wetland. Linear regression showed that differences in concentrations between drawdown and surge on this site was dependent on the change in water level (volume of water moving) during ship-passage. Three sets of conditions that could cause net import of dissolved residues to wetlands from the river are presented. The most plausible of those appears to involve leaching of ions by drawdown and surge water moving across wetland and offshore sediments that are relatively poor and relatively rich in ions respectively.

LITERATURE CITED

APHA. 1981. Standard methods for the examination of water and wastewater, 15th edition. American Public Health Association, Washington, D.C. 1134pp.

Baker, K.S. 1983. Chlorophyll determination with filter fluorometer: lamp/filter combination can minimize error. Limnol. Oceanogr. 28:1037-1040.

Glandon, R. P. 1982. Phosphate exchange between littoral sediment and lake water. Ph.D. Dissertation, Michigan State University, East Lansing, Michigan. 87pp.

Greenwood, J.O. and M.J. Dills. 1984. Greenwood's and Dills' lake boats '84. Freshwater Press, Inc. Cleveland, Ohio. 157pp.

Liston, C.R., C.D. McNabb, D. Brazo, J. Bohr, J. Craig, W. Duffy, G. Fleischer, G. Knoecklein, F. Koehler, R. Ligman, R. O'Neal, P. Roettger, and M. Siami. 1986. Limnological and fisheries studies of the St. Marys River, Michigan, in relation to proposed extension of the navigation season, 1982 and 1983. Project Report. Department of Fisheries and Wildlife, Michigan State University, Contract No. 14-16-0009-79-013. Submitted to the US Fish and Wildlife Service, Fort Snelling, Minnesota. 764pp and Appendices.

Lorenzen, C.J. 1966. A method for the continuous measurement of the in vivo chlorophyll concentration. Deep-Sea Res. 13:223-227.

NOAA. 1984. United States Coast Pilot 6. Great Lakes: Lakes Ontario, Erie, Huron, Michigan, and Superior and St. Lawrence River. National Ocean Service, Charting and Geodetic Services, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, D.C. 479pp.

Strickland, J.D.H. and T.R. Parsons. 1972. A practical handbook of seawater analysis, 2nd edition. Fisheries Res. Bd. Canada, Bull. 167, Ottawa, Canada. 310pp.

USEPA. 1979. Methods for chemical analysis of water and wastes. EPA-600 4-79-020, Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinatti, Ohio. 460pp.

Van Hall, C.E. and V.A. Stenger. 1967. An instrumental method for rapid determination of carbonate and total carbon in solutions. Anal. Chem. 39:503-507.

Wetzel, R. G. 1983. Limnology, 2nd edition. Saunders College Publishing, Chicago, Illinois. 858pp.

Wuebben, J. L. 1983. Effect of vessel size on shoreline and shore structure damage along the Great Lakes connecting channels. US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory (CRREL) Special Report 83-11. 66pp.

290

Yentsch, C.S. and D.W. Menzel. 1963. A method for determination of phytoplankton chlorophyll and phaeophytin by fluorescence. Deep-Sea Res. 10:221-231.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1987 755-569/40117

END

5-18-87